Part III

Theories of Intelligence

Intelligence Defined: Wundt, James, Cattell, Thorndike, Goddard, and Yerkes

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Most texts in the history of psychology credit Francis Galton (1822–1911) and Alfred Binet (1857–1911) as the first to develop theories of intelligence as well as instruments for its measurement. However, credit should probably go to the Victorian polymath Herbert Spencer (1820–1903) as the first to develop a substantive theory of intelligence (Guilford 1967) and one which implied—at least for Spencer—individual, racial, and species differences in intelligence. Spencer treated the empiricist principle of association by contiguity as the foundation of intelligence in both animals and humans:

> Hence the growth of intelligence at large depends upon the law, that when any two psychical states occur in immediate succession, an effect is produced such that if the first subsequently recurs there is a certain tendency for the second to follow it. (1855, p. 530)

Spencer held that intelligence is determined by the quantity and quality of adaptive associations made by organisms to their environment, by the "the continuous adjustment of internal relations to external relations" (1855, p. 374), which he believed was in turn determined by neurophysiological complexity. Consequently, he maintained that intelligence is a function of brain size.

Like Charles Darwin (1809–1882), Spencer believed in strong psychological continuity between humans and other animals: that the psychological capacities of humans and other animals differ in degree but not in fundament kind.[1] While for Darwin this just meant that complex and distinctively human capacities such as reasoning and language could be attributed to higher animals in at least insipient form, Spencer held that humans and other animals differ only in the complexity of their associative processes. For Spencer, the complex capacities of humans such as reasoning and language are merely elaborations of the basic associative processes common to all animals.

Spencer's theory was enormously influential in its day, prompting theorists such as John Hughlings Jackson (1835–1911) and Ivan Sechenov (1829–1910) to develop reflexive sensorimotor theories of the nervous system, which treated cognitive capacities such as reasoning and language as merely the pinnacles of a hierarchy of increasingly more complex and sophisticated reflexive machinery (Jackson

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[1] "The difference in mind between man and the higher animals, great as it is, is certainly one of degree and not of kind. We have seen that the senses and intuitions, the various emotions and faculties, such as love, memory, attention, curiosity, imitation, reason, &c., of which man boasts, may be found in an incipient, or even sometimes in a well-developed condition, in the lower animals." (Darwin 1871, p. 105)

S. Goldstein et al. (eds.), *Handbook of Intelligence: Evolutionary Theory, Historical Perspective, and Current Concepts*, DOI 10.1007/978-1-4939-1562-0_9,

1931; Sechenov 1863). They developed theories of strong continuity between so-called "higher" cognitive processes such as reason and language and "lower" associative or reflexive processes, mirroring Spencer and Darwin's theory of strong continuity between human and animal psychology.[2]

Thus in a very real sense, scientific psychological theories of intelligence in the nineteenth century began with theories of animal intelligence, and the question of the relation between human and animal intelligence remained a live issue for many early scientific psychologists.

Wundt and James: Apperception and Similarity

Wilhelm Wundt (1832–1920) and William James (1842–1910) are generally held to be the founding fathers of scientific psychology in Germany and America (respectively). However, neither followed Spencer in treating intelligence in terms of the complexity of association by contiguity. This is because both Wundt and James rejected the principles of strong psychological continuity—between humans and animals and between cognitive and associative processes—championed by evolutionary theorists like Spencer and experimental physiologists like Hughlings Jackson and Sechenov. Both Wundt and James championed the autonomy of a scientific psychology devoted to the study of conscious experience by rejecting what they perceived to be reductive challenges to the reality and efficacy of human conscious experience.

Thus Wundt, for example, maintained that the creative and selective attentional processes of apperception, which shape human perception and cognition, are distinct from the forms of association that humans share with animals. Like Conwy Lloyd Morgan (1852–1936), Wundt held that all animal psychology and behavior could "be accounted for by the simple laws of association" (Wundt 1863, p. 350) and treated apperception as the highest stage of distinctively human psychological evolution. Consequently, Wundt had little to say about intelligence per se, except to distinguish the forms of apperceptive intelligence—involving the creative synthesis of relational psychological elements—distinctive of humans from the forms of associative intelligence characteristic of both humans and animals.

William James managed to persuade the President and Board of Trustees at Harvard that the "new psychology" provided an intellectual bastion against the materialist threats of evolutionary psychology and experimental physiology, which according to his future colleague at Yale, George Trumbull Ladd (1842–1921), threatened to reduce conscious experience to "a stream of mechanically associated 'epiphenomena,' thrown off by the molecular machinery of the cerebral hemispheres" (1895, p. x). Like Wundt and Lloyd Morgan, James held that all animal psychology and behavior could be explained in terms of association by contiguity and claimed that distinctive human cognition went beyond this to the recognition of similarities and analogies:

> We may then, we think, consider it proven that *the most elementary single difference between the human mind and that of brutes lies in this deficiency on the brute's part to associate ideas by similarity*—characters, the abstraction of which depends on this association, must in the brute always remained drowned, swamped in the total phenomenon which they help constitute. (James 1890, p. 360)

While James did not develop a theory of intelligence per se, it is clear that he thought that the most intelligent men and women were those who were able to most fully develop their ability to form associations by similarity:

> Genius then, as has been already said, is identical with the possession of similar association to an extreme degree. (1890, p. 360)

[2]Although it is doubtful if Darwin himself thought that rationality and language are just more complex elaborations of associative or reflexive processes. That is, he seems to have held that cognition and association are psychologically discontinuous, even though he held that the psychology of humans and animals is strongly continuous: he seems to have supposed that the *discrete* higher cognitive capacities of humans—such as rationality and language—could be found in animals, in at least incipient form.

Although neither Wundt nor James developed substantive theories or measures of intelligence, a number of their students did and made major contributions to debates about the nature of intelligence in the early twentieth century. To these we now turn.

Cattell and Mental Testing

James McKeen Cattell (1860–1944) was one of Wundt's earliest Leipzig students and his first full-time American student. He also became Wundt's first research assistant, based upon Cattell's own recommendation (Boring 1957). While at Leipzig, Cattell did experimental studies of the time taken to complete "cerebral operations," a topic suited to Wundt's program of research on mental chronometry, based upon measures of reaction time.[3] Cattell's paper "On the Time It Takes to See and Name Objects" was published in Wundt's journal *Philosophical Studies* in 1885 (Cattell 1885); a shorter version appeared in the British journal *Mind* a year later (Cattell 1886).

Most unusually, Wundt also allowed Cattell to pursue research on individual differences in reaction time, a topic that was anathema to Wundt, who refused to allow students like Edward B. Titchener (1867–1927) and Lightner Witmer (1867–1956) to participate in reaction time experiments because they were not properly "calibrated" (trained) to reproduce the supposedly universal measures of sensory and motor reaction times (O'Donnell 1985). This may have been because Wundt respected Cattell's intellectual independence and self-confidence, qualities Wundt characterized as "typically American."

There was, however, one major theorist who recognized individual differences in sensory and motor reaction times, and that was Francis Galton (1822–1911), with whom Cattell went to study in England after he completed his degree in Leipzig in 1886. Galton, who was Darwin's half cousin, maintained that individual differences in sensorimotor reaction times were a natural consequence of the chance distribution of inherited characteristics described by Darwin in *On the Origin of Species* (Darwin 1857) and set about measuring these differences in the general population. Galton gathered data on nearly 20,000 people at his anthropometric laboratories at the International Health Exhibition in London (in 1884) and the Science Galleries of the South Kensington Museum (in 1888), employing physical and sensory acuity measures, such as head size, physical strength, visual and auditory acuity, and reaction time.

Galton claimed that sensory acuity was correlated with intelligence and thus could serve as a convenient indirect measure of intelligence. Galton also later claimed that he had demonstrated the correlation, based upon the statistical measures of correlation that he developed toward the end of the 1880s (Galton 1888), although he seems to have come to this conclusion sometime earlier. For example, in *Inquiries Into Human Faculty* (1883), Galton announced:

> The trials I have as yet made on the sensitivity of different persons confirm the reasonable expectation that it would on the whole be highest among the intellectually ablest. (1883, p. 20)

In this peculiar fashion, the measures of sensory acuity and reaction time developed by Wundt and his students in the Leipzig laboratory were appropriated by Galton, and later by Cattell, as measures of intelligence.

Galton also employed his newly developed statistical measures—and his pioneering use of twin studies—to supposedly demonstrate that human intelligence is largely determined by heredity. While the statistical calculations of *Natural Inheritance* (Galton, 1889) are impressive, the data on which they were founded are doubtful, based upon family records anonymously submitted by correspondents hoping to win the cash prizes for best entries offered by Galton (Boakes 1984).

Given his commitment to the hereditarian determination of intelligence, Galton was

[3] This program was based upon the complication experiments of the Dutch physiologist Franciscus Cornelis Donders (1818–1889), in which the time taken for components of a complex mental task was calculated by subtracting the time taken for other components of the task.

consequently dismissive of optimistic utilitarian theories—such as those advanced by John Stuart Mill (1806–1873)—that held that all human beings are capable of attaining the same intellectual and moral levels, given similar nurturing experiences. As Galton put it (once again in advance of his statistical calculations):

> I have no patience with the hypothesis …that babies are born pretty much alike, and that the sole agencies in creating differences between boy and boy, and man and man, are steady application and moral effort. It is in the most unqualified manner that I object to pretensions of natural equality. (Galton 1869, p. 12)

Although Galton did not believe that the intelligence levels of men and women could be significantly raised through education, he did think they could be raised through selective breeding. Like others who reflected on Darwin's theory of evolution, Galton recognized that natural selection operating on chance variations would not ensure the evolution of socially desirable characteristics like high intelligence and moral virtue and indeed might very well lead to their attenuation, if "idiots and imbeciles" were allowed to overbreed. Galton coined the term eugenics (Greek for "wellborn") to describe his recommended form of artificial selection, designed to produce more intelligent and productive human stock (as farmers used selective breeding to produce desired qualities in their animal stock, such as high quality of fleece in sheep and body mass in cattle).

Originally, Galton recommended a form of positive eugenics. He thought that those persons identified as the most intelligent (via his sensory acuity measures) should be encouraged to breed, and to breed regularly, via financial inducements provided by the government. However, in reaction to the moral panic created by the failure of the mighty British Empire to crush a nation of farmers in the Second Boer War (1899–1902), Galton and his protégé Karl Pearson (1857–1936) recommended a form of negative eugenics through institutionalization and sterilization of the "idiots and imbeciles."

Cattell was greatly impressed by Galton's work, which reinforced his own interest in individual differences. He also embraced Galton's theory of the hereditarian determination of intelligence and contributed his small share to the program of positive eugenics by offering each of his seven children one thousand dollars if they married college professors. When he returned to America for a position at the University of Pennsylvania, Cattell began to use the techniques he had developed at Leipzig for his own anthropometric studies and initiated a program of "mental testing" based upon psychophysical measures of grip strength, speed of movement, skin sensitivity, and sensory and motor reaction times. In a paper published in *Mind* in 1890 (Cattell 1890), Cattell extolled the utility of such "mental tests," and when he moved to Columbia in 1891, he subjected hundreds of students to them.

Like Galton, Cattell assumed that his tests of sensory acuity were indicators of intelligence and consequently assumed that there would be a significant correlation between test scores and academic performance. However, at the turn of the century, one of Cattell's own students, Clark Wissler (1870–1947), tried to demonstrate this by measuring the degree of correlation between performance on 21 of Cattell's mental tests and course grades, employing the Galtonian measures of correlation (including Pearson's newly developed correlation coefficient). To Cattell's consternation, Wissler (1901) found no correlation between the test scores and the grades, nor between the tests scores themselves (although he did find correlations between the student's grades). This effectively brought to an end to the program of the Galtonian anthropometric intelligence testing in the United States.[4] However, intelligence testing would shortly resurface in an entirely different guise.

Spearman and the "g" Factor

Wissler's studies were not quite the end of the Galtonian psychometric story, however, although they are commonly supposed to have been.

[4]Although it was continued for a few years by Joseph Jastrow (1863–1944) at the University of Michigan.

Charles Spearman (1863–1945), after serving as a regular officer in the British Army for 15 years, resigned his commission in 1897 to study for a doctoral degree in Wundt's Laboratory. While at Leipzig, Spearman was surprised to learn about Wissler's results, but eventually came to the conclusion that Wissler's data were unreliable and that he had underestimated the degree of relationship between them. Using a corrective statistical formula, Spearman was able to demonstrate positive correlations between the test scores and between the test scores and academic grades. He parleyed this success into his theory that the correlation between various mental tests could be explained by reference to a single, unitary capacity, or general factor "g," which he identified via a new statistical technique that came to be known as factor analysis.[5]

Spearman called his theory, which he also developed and published while a student at Leipzig, as the "law of the universal unity of the intellectual function":

> Whenever branches of intellectual activity are at all dissimilar, then their correlations with one another appear wholly due to their being all variously saturated with some common fundamental Function (or group of Functions). (Spearman, 1904, p. 124)

Like Galton and Cattell, Spearman also believed that this general factor ''g'' is innate:

> G is in the normal course of events determined innately; a person can no more be trained to have it in higher degree than he can be trained to be taller. (Spearman 1931, in Deary et al 2008, p 157)

After Leipzig, Spearman returned to England and took up a position at University College, London, where he continued to develop his theory of intelligence. His theory was later criticized by Sir Geoffrey Thompson (1881–1955), who argued that although g was a statistical reality, it did not designate a unitary intelligence factor, but a variety of highly correlated intellectual skills (Thomson 1916). Spearman did not always insist on the unitary nature of the g factor, at least in his later work (Spearman 1925). He believed g to be grounded in two "ubiquitously" cooperating abilities: an educative ability to make "meaning from confusion" and a reproductive ability to recall that meaning. And although Spearman remained a champion of intelligence testing and of the view that the innate g factor accounted for most individual differences of intelligence, he thought that intelligence testing had no place in schools, which ought to be engaged in maximizing the varied native abilities of individual students.[6]

Thorndike and Connectionism

Edward L. Thorndike (1874–1949) was a student of William James and received his master's degree at Harvard in 1897. Like James (and Wundt), he was not impressed by anecdotal reports of the apparently intelligent behavior of animals, such as the apparent rationality of animals reported by Darwin in *The Descent of Man, and Selection in Relation to Sex* (Darwin 1971)[7] or their apparent knowledge of mathematical and mechanical principles reported by George Romanes (1848–1894) in *Animal Intelligence* (Romanes 1882).[8] Thorndike disparaged anecdotal accounts of animal behavior because he maintained they were generally unrepresentative of animals' cognitive abilities:

> Dogs get lost hundreds of times and no one ever notices it or sends an account of it to a scientific magazine. But let one find his way from Brooklyn to Yonkers and the fact immediately becomes a circulating anecdote. Thousands of cats on thousands

[5]Strictly speaking, Spearman developed a two-factor theory of intelligence, postulating a general factor "g" common to all tasks requiring intelligence and a factor "s" specific to different kinds of intellectual tasks (Sternberg 2003).

[6]Unlike his later colleague at University College, Sir Cyril Burt (1883–1971), who promoted the 1940s British government program of intelligence testing in schools—the "11 plus" exam—on the basis of which students were streamed into academic or trade classes.

[7]Darwin claimed that most people would agree that "animals possess some power of reasoning," on the grounds that they "may constantly be seen to pause, deliberate, and resolve" (1871, p. 46).

[8]Darwin bequeathed his notebooks on animal behavior to Romanes after the two men became close friends toward the end of Darwin's life.

> of occasions sit helplessly yowling, and no one takes thought of it or writes to his friend, the professor; but let one cat claw at the knob of a door supposedly as a signal to be let out, and straightway this cat becomes the representative of the cat-mind in all the books…In short, the anecdotes give really the *abnormal* or *supernormal* psychology of animals. (Thorndike 1911, pp. 23–25)

Thorndike insisted that the scientific study of animal "intelligence" should be based upon carefully controlled experimental studies, which he began with chickens in William James's basement and continued at Columbia University when Cattell offered him a fellowship there in 1897. At Columbia, Thorndike began a series of experiments in which food-deprived cats learned to escape from specially constructed slatted cages or "puzzle boxes" to gain a food reward, described in his doctoral dissertation of 1898, and published later that year as *Animal Intelligence: An Experimental Study of the Associative Processes in Animals* (Thorndike 1898) as a monograph supplement in *Psychological Review*[9].

Thorndike's studies were based upon Lloyd Morgan's (1894) explanation of how his dog Toby had learned to lift the latch on the gate of the back courtyard of his house to escape into the street. Based upon his repeated observation of the dog's behavior, Lloyd Morgan dismissed Romanes's (1882) explanation of such behavior in terms of the dog's understanding of mechanical principles and noted how after accidentally stumbling on a means of lifting the latch by a movement of its head the dog had managed to learn after repeated trial and error how to open the gate. Similarly, Thorndike's cats initially clawed at the bars and pushed their paws between them, until they accidentally hit on the movement required to release the latch. Like Morgan, Thorndike found that the animals took progressively less time to hit on the required behavior over a series of trials, until eventually they produced the learned behavior the moment they were placed in the box.

On the basis of these experiments, Thorndike articulated what he called the "law of effect," linking learning with reinforcement, and the "law of exercise," linking learning with repetition.

Thorndike was at pains to insist that learning was not based upon imitation or insight and that connections between behavior and response were "stamped in" by reinforcement and repetition. Consequently, he called his theory "connectionism" and on the basis of his limited experiments maintained that all animal and human behavior could be explained in terms of the laws of effect and exercise and instinct:

> The higher animals, including man, manifest no behavior beyond expectations from the laws of instinct, exercise and effect. (Thorndike 1911, p. 274)

While he was later forced to modify the law of effect and drop the law of exercise, Thorndike continued to insist that learning was based upon connections or associations. So although he rejected Darwin and Romanes's attribution of higher cognitive processes such as rationality and mechanical understanding to animals, he maintained—with Spencer—that higher cognitive processes are nothing more than complex forms of connection or association, based ultimately upon the same psychological and physiological principles:

> …the higher forms of intellectual operations are identical with mere association or connection forming, depending upon the same sort of physiological connections but requiring *many more of them*. (Thorndike et al. 1926, p. 415)

Consequently, he supposed that an individual's level of intelligence was determined by the number of connections that individual was capable of making:

> By the same argument the person whose intellect is greater or higher or better than that of another person differs from him in the last analysis in having, not a new sort of physiological process, but simply a larger number of connections of the ordinary sort. (Thorndike et al. 1926, p. 415)

While he recognized the difficulty of determining the nature and number of connections that needed to be made to in order to execute a complex human cognitive process such as language comprehension, Thorndike developed his own intelligence tests when he took up a full-time

[9] It was republished as an independent monograph in 1911 (Thorndike 1911).

position at Teachers College, where he remained for the rest of his career, devoting much of his time to educational psychology and the development of tests for education (mainly on reading and writing). Although he came to his theoretical conception of human intelligence by a different route than Galton, Cattell, and Spearman, Thorndike was equally committed to the view that intelligence was largely determined by hereditary, publishing *Heredity, Correlation and Sex Differences in School Abilities* in 1903 (Thorndike 1903).

Goddard and the Binet-Simon Intelligence Scale

A good case can be made for the claim that Granville Stanley Hall (1844–1924), rather than William James, deserves to be credited as the founding father of scientific psychology in America. Although Hall was himself a student of James, he was the first to complete a PhD at Harvard on a psychological topic (with a dissertation on spatial perception). He was also the first to set up a fully developed psychological laboratory and PhD program in psychology at Johns Hopkins University in 1884,[10] which he transferred to Clark University in 1888. Hall is mainly remembered for his contributions to educational psychology and (like Wundt and James) had little to say about intelligence and its measurement, but he did have two graduate students who made significant contributions to the field.

Henry Goddard (1866–1957) graduated from Clark University in 1899 and became Director of the Research Laboratory for the Study of Feeblemindedness at the Vineland Training School for Feeble-Minded Boys and Girls in New Jersey in 1906. He translated the 1908 Binet-Simon scale for measuring children's intelligence into English and also the revised 1911 Binet-Simon scale. This became the standard measure of intelligence in the United States until Lewis Terman (1877–1956), a Clark University graduate of 1905 who secured a position as Professor of Child Study at Stanford University, brought out what came to be known as the Stanford-Binet scale in 1916.

In 1905 Alfred Binet (1857–1911) and his research assistant Theodore Simon (1873–1961) had developed a test for measuring children's intelligence, as a means of assessing the child's "mental level" (the tests were designed to ensure that most children at any age would test at the appropriate mental level). Unlike Galton and Cattell's tests, Binet and Simon's tests were based on direct measures of intellectual abilities such as comprehension, problem solving, and logical and analogical reasoning—all forms of intelligent judgment. Their scales consisted of thirty items, ranked in order of difficulty, so that everyone could do the easier ones, and children scored progressively better with every increase in "mental level."

Binet and Simon's test items represented what Spearmen called a "hodgepodge" of factors, but they did the job for which they were designed, namely, to provide an objective means of identifying children in need of remedial education. Unlike Spearman, Binet and Simon did not suppose that they were measuring a unitary capacity, far less one that is innately determined. On the contrary, they designed programs of remedial education for those children who tested below the mental level of their age group, designed to increase their mental level through special training methods called "mental orthopedics" (which involved exercises in attention, will, and discipline). The Binet-Simon scale was administered to French schoolchildren between 1905 and 1908 and was judged to be a great success in Europe. It was seen as an objective measure of intelligence that was easy to administer and was translated into many languages.

Binet and Simon were careful to stress the limitations of their scales, given their belief in the malleability of intelligence and the inherent margin of error. However their cautious approach was discarded when Goddard and Terman

[10] Although William James set up a laboratory of sorts at Harvard in 1875, it was little more than a small collection of instruments housed in a stairwell closet (Hall 1923, p. 218), and Harvard did not attain an independent (of philosophy) psychology department until 1937.

brought the Binet-Simon scales to the United States—both followed Galton, Cattell, and Spearman in supposing that intelligence was a unitary ability, which was largely determined by heredity. In 1914, William Stern (1871–1938) had introduced the theoretical notion of a mental quotient, defined as a child's mental age—as determined by their performance on the Binet-Simon scale—divided by their chronological age (Stern 1914), and Terman defined the intelligence quotient (IQ) as Stern's mental age multiplied by 100, so that the average intelligence quotient for any mental age would be 100. Goddard and Terman used these IQ scales to define levels of intelligence and "feeblemindedness," or as Terman put it bluntly in his PhD dissertation at Clark University, "genius and stupidity" (Terman 1906).

Goddard was convinced of the utility of the tests as measures of intelligence and trained teachers at local schools to administer them. He was not surprised to find that the scores for inmates at Vineland were much lower than those of children in the regular public schools but was concerned to discover that many of the public schoolchildren scored lower than their age norms, which Goddard took as a disturbing indicator of the extent of feeblemindedness in the general population.

Goddard also impressed the immigration officers at Ellis Island with his apparent ability to identify feebleminded immigrants by sight and then have his identification "objectively" confirmed by their low scores on the Binet-Simon tests. Goddard trained assistants to identify the feebleminded and administer the tests, and eventually they came to be employed by the inspectors themselves, although some objected that they included questions (e.g., about the New York Giants) that they would not have been able to answer when they first came to the country. Nevertheless, the use of psychological testing methods for screening immigrants was judged to be a great success, and the number of persons deported on grounds of feeblemindedness increased dramatically. Again, Goddard drew a pessimistic conclusion about the high percentage of feeblemindedness among recent immigrants of "poor stock," that is, among the increasing number of immigrants from Eastern and Southern Europe, as opposed to the earlier and supposedly "superior stock" from Northern and Western Europe.

Goddard had also read the works of Galton and Mendel and had noted that many brothers and sisters of the children at Vineland were also feebleminded themselves, which he operationally defined as having an IQ of less than 70. In 1911, he set out to demonstrate the inheritance of feeblemindedness, which he believed to be caused by a recessive gene, by exploring the family tree of a 22-year-old Vineland girl whom Goddard had named Deborah Kallikak. She performed on the Binet-Simon scale at the mental level of 9 years, on the basis of which Goddard classified her as a moron, a technical term (meaning dull) introduced by Goddard to describe those with an IQ of between 50 and 70.

Goddard set about exploring her family tree, which he found could be traced back to one Martin Kallikak, a Revolutionary War soldier. Martin had married an upstanding Quaker girl, who had borne him seven children. The descendants of this "good" side of the family tree had gone on to become upright citizens, such as lawyers, doctors, judges, teachers, and landed gentry. However, Martin Kallikak had also dallied with a serving wench of loose morals, who had borne him an illegitimate son, Martin Kallikak junior, who fathered ten children. The descendants of this "bad" side of the family turned out to be horse thieves, brothel owners, prostitutes, and alcoholics. Goddard claimed to have discovered a high incidence of feeblemindedness among the offspring of the serving wench and a low incidence among the offspring of the upstanding Quaker girl.

This study, published in 1912 as *The Kallikak Family: A Study in Feeblemindedness* (Goddard 1912), confirmed Goddard in his belief that feeblemindedness and intelligence are inherited, and that feeblemindedness was the root cause of licentiousness and criminality. Although Goddard promoted the study as a "natural experiment," there was no attempt to control for environmental or social differences, and Goddard and his coworkers, like many asylum and prison superintendents of his day, simply equated immoral and criminal behavior with feeblemindedness. Nevertheless, Goddard's conclusions were widely accepted and regularly cited, and his study spawned a spate of similar studies supposedly demonstrating the link between feeblemindedness and social degeneration (Zenderland 1998). Many also accepted the implied threats to the "national stock" posed by the overbreeding of what Galton had called "the idle and the infirm" and the influx of recent immigrants of poor stock.

For Goddard, the moral and social implications were as clear as they were for Galton, namely the need for eugenic programs designed to prevent the breeding of the feebleminded. Goddard served as psychology representative on the 1911 Committee to Study and to Report on the Best Practical Means of Cutting Off the Defective Germ-Plasm in the American Population, established by the Eugenics Section of the American Breeders Association, which recommended the segregation and sterilization of mental defectives, mercifully drawing the line against euthanasia. Goddard also served on the 1913 Committee for the Heredity of Feeblemindedness, which included fellow psychologists Edward Thorndike, Lewis Terman, and Robert M. Yerkes (1876–1956), as well as the inventor Alexander Graham Bell (1847–1922) and the Harvard physiologist Walter B. Canon (1871–1945), which also recommended that "defective classes" be eliminated through sterilization.

Such eugenic ideas were not themselves a product of intelligence testing, but had been in circulation since the beginning of the century. Charles Davenport (1866–1944), the author of *Eugenics: The Science of Human Improvement by Better Breeding* (1911), had founded the Eugenics Records Office at Cold Spring Harbor, New York, in 1910, and similar societies and organizations had been founded in Canada and Europe. However, the major impetus of the development of eugenics legislation in the United States was the result of the program of intelligence testing in the United States Army conducted during the First World War, engineered by the psychologist Robert M. Yerkes.

Yerkes and the Army Testing Project

Robert M. Yerkes originally came to Harvard as a graduate student in zoology, but the philosopher Josiah Royce (1855–1916) persuaded him to combine his interests in zoology and psychology to study comparative psychology. Yerkes transferred to the philosophy department, then headed by James's successor, Hugo Münsterburg (1863–1916), and received his PhD degree in 1902. Münsterburg managed to secure Yerkes an assistantship and later an assistant professorship in the department, where he developed "criteria of the psychic" (Yerkes 1905), which supposedly provided researchers with objective grounds for the attribution of higher cognitive states to animals, as a means of assessing their intelligence.[11] However, Münsterburg objected to Yerkes's failure to follow his advice to devote more of his time to educational psychology and threatened to shut down the comparative psychology program. Fortunately, Yerkes secured a position as state psychologist at Boston Psychopathic Hospital just before the First World War, which also enabled him to keep a half-time teaching position at Harvard at double his former pay.

In later years, Yerkes became known for his seminal contributions to comparative psychology, but during his time at Boston Psychopathic Hospital, he developed his own intelligence test, the Yerkes-Bridges Point Scale of Intelligence (Yerkes et al. 1915). Yerkes was also a born organizer and administrator, and his great chance came in April 1917, when Titchener's Experimentalists were meeting at Harvard. Yerkes was serving that year as President of the American Psychological Association and, on receiving the news that America had entered the

[11] John B. Watson (1878–1958), who was a friend of Yerkes, was so skeptical of his criteria for the objective determination of animal cognition and intelligence that he began to promote the claim that animal psychology should be restricted to the description of observable stimulus–response sequences (Watson 1909), a position he extended to human psychology 4 years later in his "Psychology as a Behaviorist Views It" lecture at Columbia (Watson 1913).

First World War, chaired a special session on the proposed contribution of psychologists to the war effort. Shortly afterward, Yerkes traveled to Canada to study the contribution of Canadian psychologists to the war effort, and later that month, at the meeting of the APA Council in Philadelphia, he formed a committee to explore ways in which American psychologists could contribute. This committee, whose members included Cattell, Hall, Thorndike, and Watson, suggested the development of psychological tests to facilitate the selection of officers and the discharge of feebleminded recruits. Yerkes promptly formed the Committee on Methods of Psychological Examining for Recruits, whose members included Goddard and Terman, which spent 2 weeks at Vineland creating group intelligence tests for the army and running trials at local institutions and army bases.

When the army finally approved what became known as the Army Testing Project, some 400 commissioned psychologists administered group intelligence tests to some two million soldiers between 1917 and 1919: the Alpha[12] test to literate soldiers and the Beta (pictorial) test to illiterates. The mass testing was of doubtful military utility, and the army discontinued the project at the end of the war (Samelson 1977), although it did serve to promote the public perception of the utility of intelligence testing and the professional status of psychologists—as Cattell put it, the Army Testing Project "put psychology on the map" (Cattell 1922, p. 5). Yerkes was appointed to the National Research Council, where he worked on the development of the National Intelligence Test (National Research Council 1920), administered to over seven million schoolchildren in the 1920s.

However, the most important outcome of the Army Testing Project was the alarming finding that around half the army recruits tested at or below the level of moron. In his final report on the project, Yerkes concluded that "feeblemindedness …is of much greater frequency than has been previously supposed" (Yerkes 1921, p. 789). This led to a moral panic analogous to that generated in Britain by the poor performance of the British army during the Second Boer War and promoted similar fears about the decline in "national efficiency." These fears were stoked by books like Madison Grant's *The Passing of the Great Race* (Grant 1916), Goddard's *Human Efficiency and Levels of Intelligence* (Goddard 1920), and Carl Brigham's *A Study of American Intelligence* (Brigham 1923, with a foreword by Yerkes), which claimed that the average intelligence of Americans had declined since the turn of the century due to the overbreeding of recent immigrants from Eastern and Southern Europe, which was itself seen as a sign of feeblemindedness.

While there were those who urged caution in drawing conclusions from the army data (Boring 1923a) and those who disputed Goddard's (Goddard 1919) claim that they demonstrated that the average intelligence of adult Americans was below the level of moron (Freeman 1922; Lippmann 1922), they were drowned out by more strident calls for immigration quotas and programs of sterilization of the feebleminded.

In 1924, the Congress passed the National Origins Act, which imposed quotas on the nationality of immigrants based upon the 1890 census (i.e., before the wave of Eastern and Southern European immigration at the turn of the century). Harry Laughlin (1880–1943) of the Eugenics Records Office had testified before the Congressional Immigration and Naturalization Committee earlier that year, claiming that the American gene pool was being "polluted" by the growing numbers of intellectually inferior immigrants.

By the end of the 1920s, close to 30 states[13] had passed laws legitimizing the compulsory sterilization of the feebleminded, a procedure

[12]Carl Brigham (1890–1943), who worked on the Army Alpha test, later adapted it as an admissions test when he joined the faculty at Princeton University, where it became known as the Scholastic Admissions Test (SAT) and later as the Scholastic Assessment Test.

[13]The first state law licensing the compulsory sterilization of confirmed criminals, idiots, imbeciles, and rapists was passed by Indiana in 1907, on the recommendation of Harry Clay Sharp (1869–1940), a pioneer of vasectomy, who originally used the procedure to treat masturbation, which he believed to be a major cause of intellectual degeneracy. The 1907 Indiana Law was struck down by

inflicted on at least 12,000 inmates by 1930. In 1926, the US Supreme Court put its seal of approval on the eugenic use of the procedure by sanctioning the sterilization of Carrie Buck (1906–1983), a 17-year-old girl who was an inmate of the Virginia Colony for the Epileptic and Feebleminded. Carrie and her mother, who was also an inmate, were judged to be feebleminded, as was Carrie's illegitimate daughter Vivian, and Carrie was sterilized by court order under Virginia's Eugenical Sterilization Act.[14] The case was appealed to the US Supreme Court, which upheld the Virginia Law, with Oliver Wendell Holmes Jr. (1841–1935), who wrote the majority opinion in the case of Buck vs. Bell in 1927, famously declaring:

> It is better for all the world if instead of waiting to execute degenerate offspring for crime, or let them starve for their imbecility, society can prevent those who are manifestly unfit from continuing their kind. Three generations of imbeciles are enough. (Buck vs. Bell 1927, p. 207)

Eventually, the eugenic excesses of the Nazis—who did endorse euthanasia on a grand scale—demonstrated the dangers of this overreaching science and dampened the enthusiasm of many former supporters. Many original psychological advocates, such as Goddard and Brigham, recanted their original positions.[15] And Yerkes, although he continued to believe in genetically determined racial differences in intelligence, recognized that the topic had become too hot to handle and shifted his attention back to comparative psychology. Nonetheless, the quota system established by the National Origins Act remained in place until 1965, and the sterilization laws remained on the books for many years later, with the State of Virginia repealing the last law as late as 1981.

Conclusion: So What Is Intelligence?

Beyond the *Sturm und Drang* over the inheritance of intelligence and feeblemindedness, what was learned about the nature of intelligence itself? Not much it seemed. In a 1921 study published in the *Journal of Educational Psychology* that canvassed the definitions of intelligence by 14 "experts" (Thorndike et al 1921, there was remarkably little agreement, and many practitioners of intelligence testing rested content with Boring's (1923b) operational definition of intelligence as what intelligence tests measure, which seemed sufficient to guarantee its reference while saying nothing about its nature. Nevertheless, one can discern at least the outline of a common theme running through the works of Wundt, James, Spearman, Thorndike, and the developers of the Binet-Simon tests of intelligence. Wundt's apperceptive synthesis of relational elements, James' discernment of similarities, Spearman's "education" of relations and correlates, Thorndike's formation of connections, and Binet and Simon's trio of "comprehension, invention, and direction" all point to some form of cognitive achievement involving the discernment or determination of connections and configurations. However, it would take the development of cognitive psychology in the later part of the century to begin to specify the relevant cognitive processes, while still leaving open and contentious the original question of whether "higher" cognitive processes such as logical reasoning and abstract thought are continuous with "lower" forms of association and whether human intelligence is continuous with animal intelligence (Mitchell et al. 2009; Penn et al. 2008; Shanks 2007).

the state supreme court in 1921, but was quickly replaced by another that survived legislative challenge.

[14] There is little evidence that Carrie was feebleminded, and she seems to have been institutionalized on grounds of sexual promiscuity—commonly treated as an indicator of feeblemindedness—on the basis of her pregnancy, despite the fact that this was the result of a rape by a nephew of the foster parents who committed her. Nor is there much evidence that Carrie's daughter Vivien was feebleminded. Although she died at the age of eight of an intestinal disease, her first grade report card indicated that she was a solid B student, with an A in deportment, who once made the honor role.

[15] Brigham also repudiated the use of the Scholastic Achievement Test as a measure of intelligence (Angier et al. 1926) and opposed its use as the basis of a National Educational Testing Service (Brigham 1938).

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Piaget's Theory of Intelligence

10

Ulrich Müller, Kayla Ten Eycke, and Lesley Baker

[I]ntelligence, the most plastic and at the same time most durable structural equilibrium of behavior, is essentially a system of living and acting operations

(Piaget 1976a, p. 7)

Readers may be puzzled by the quote above because the way in which Piaget uses the term intelligence is rather broad and does not correspond with the more tightly defined way in which it is used today. Puzzlement likely will make way to outright confusion when the reader attempts to make sense of Piaget's definition of intelligence: "Intelligence constitutes the state of equilibrium towards which tend all the successive adaptions of a sensori-motor and cognitive nature, as well as all assimilatory and accommodatory interactions between the organism and the environment" (Piaget 1976a, p. 11). This quote is taken from the book *The Psychology of Intelligence*, but despite its title, the following pages of the book might do little to lift the reader's confusion. In this book, there is no description of any method by means of which intelligence might be assessed in order to assign individuals a particular number (their IQ), nor does it refer to individual differences in intelligence, nor does it identify specific cognitive processes such as working memory or processing speed as being involved in intelligence, nor is there a discussion of a specific neural basis of intelligence, nor is any attempt being made to understand intelligence in the context of the selection pressures exerted by the environment of evolutionary adaptedness. Instead, in the first part of the book the reader encounters a classification of theories of intelligence, a discussion of old theories of intelligence (e.g., Russell's theory of logical atomism, the Wùrzburg school of thought psychology, Gestalt psychology), and remarks on the relation between logic and psychology that culminate in a mathematical treatment of higher states of equilibrium.

The goal of this chapter is to clarify Piaget's theory of intelligence. We attempt to do this by first showing how Piaget's conception of intelligence builds on that of his contemporaries. Next, we describe how his conception of intelligence is contextualized within his larger theoretical framework, his genetic epistemology. This leads us to a discussion of core features of Piaget's theoretical framework such as self-organization,

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assimilation and accommodation, and operative and figurative aspects of intelligence. We next summarize the four major stages of the development of intelligence. Finally, we describe how Piaget's theory of intelligence relates to semiotic function, affectivity, and social interaction.

Piaget's Definition of Intelligence

Similar to his contemporaries (e.g., see Binet 1894, 1975), Piaget uses the term intelligence in a broad sense, a common practice commented on already by the French historian Taine (1872, p. vii): "If I am not mistaken, we mean nowadays by intelligence, what was formerly called Understanding or Intellect—that is to say, the faculty of knowing." Reflecting such a broad sense of intelligence, Piaget (1976a, pp. 8–9) identifies a central feature of intelligence as a movement toward increasing spatiotemporal distances in the functional interaction between subject (i.e., person, animal) and world.

Piaget (1976a, p. 9) notes that a problem arises when we want to draw a line and precisely demarcate behavior that is intelligent from behavior that is not. He illustrates this by comparing a variety of different definitions of intelligence. For example, Karl Bühler (1933) distinguishes between three stages of purposeful behavior: instinct, training, and intellect. Instinctive behaviors are innate, rigid, and executed in the same manner in all members of a species. Training involves trial-and-error learning such that successful behaviors are reinforced and unsuccessful ones are eliminated, which allows individuals to adapt to new situations. True intelligence emerges at the stage of the intellect at which the individual "*makes discoveries by means of insight and reflection.* INVENTION, in the true sense of the term, is the biological achievement of the intellect" (Bühler 1933, p. 10; emphases in original). Piaget (1976a, pp. 9–10) contrasts Bühler's definition with that of Claparède (1917), who argues that the defining feature of intelligence is the adaptation to new situations. As a result, Claparède considers trial-and-error behavior as intelligent behavior and distinguishes it from instinct and habit (see Piaget 1963, pp. 395–407, for an extended discussion of Claparède's theory of intelligence).

Given these contradictory ways of demarcating intelligent and unintelligent behaviors, Piaget (1976a, p. 10) saw himself confronted with the following alternatives:

> [E]ither we must be satisfied with a functional definition at the risk of encompassing almost the entire range of cognitive structures, or else we must choose a particular structure as our criterion, but the choice remains arbitrary and runs the risk of overlooking the continuity which exists in reality.

Piaget (1976a) resolved this issue by combining functional continuity and structural change and defined intelligence in terms of the direction in which development moves, "without insisting on the question of boundaries, which become a matter of stages of successive forms of equilibrium" (p. 10). From the functional perspective, behavior becomes more intelligent as the spatiotemporal distance between person and world increases. At the same time, functional continuity implies that there is neither an absolute starting point for intelligence nor a predetermined end point: "it is an ultimate goal, and its origins are indistinguishable from those of sensori-motor adaptation in general or even from those of biological adaptation itself" (Piaget 1976a, p. 7). From the point of view of structure, earlier stages of development are characterized by a lack of reversibility, with intelligence moving toward increasingly reversible mobility. Let us now examine this definition in the context of Piaget's theoretical framework.

Genetic Epistemology

Piaget (1950a, b, c) called his theoretical framework genetic epistemology. Here, genetic specifies developmental. Epistemology refers to the study of the nature, sources, scope, and validity of knowledge. Usually, epistemology is considered a branch of philosophy, and empirical research is argued to have no bearing on epistemological questions (Hamlyn 1971). Piaget, however, did not believe that epistemological issues fall under the sole jurisdiction of philosophy. One important reason for this is that knowledge itself is in constant flux and always remains incomplete. In this context, Piaget (1972a, p. 2) approvingly quotes the neo-Kantian philosopher Natorp (1910, pp. 14–15):

> Like Kant, we start with the actual existence of knowledge and seek the basis from there. But what is this existence since, as we know, knowledge is constantly evolving? Progression, method is everything… in consequence, the existence of knowledge cannot be comprehended except as a *fieri* (i.e., to be made, to become; authors' note). This *fieri* alone is the fact. Any entity (or object) which knowledge attempts to crystallize must dissolve again in the current of development. It is in the last phase of this development, and in this alone, that we have the right to say: "this is (a fact)." What we can and must seek, then is the law underlying this process.

Hence, if constant evolution is constitutive of scientific knowledge, as witnessed in the natural and human sciences, and even in logic and mathematics (Piaget 1950a, b, 1972a, b), then the study of the conditions of the possibility of knowledge must include the development of knowledge. The study of the development of knowledge, in turn, falls under the purview of the empirical sciences.

Thus, although Piaget is mostly known as a child psychologist, the study of cognitive development in children was for Piaget only a means to address epistemological issues (Vonéche and Vidal 1985). Piaget's focus on epistemological issues explains why he was not at all interested in determining the cognitive level of an individual child or in examining interindividual differences in cognition (see Bringuier 1980, p. 86). Instead, he was interested in what is common to all persons at a specific level of thinking—what Piaget (1987) referred to as the epistemic subject. The epistemic subject is able to attain states of knowledge, and the goal of genetic epistemology is to explain how the attainment of this knowledge is possible. Knowledge, however, "is not to be naively equated with mere belief (or the brute factual existence of a cognitive structure): knowledge has an inescapable normative dimension, one concerning concepts like evidence, objectivity, rationality, validity, truth, etc." (Kitchener 1993, p. 141).

Piaget argued that the normative dimension of knowledge cannot be reduced to causality. He often used the necessary truth of arithmetic judgments as an example to illustrate this irreducibility:

> [the] truth of 2+2=4 is not the 'cause' of the truth of 4–2=2 in the same way that a cannon causes the movement of two billiard balls, or a stimulus is one of the causes of a reaction: the truth … of 2+2=4 'implies' that of 4–2=2, which is quite a different matter (Piaget 1968, p. 187).

The normative dimension of knowledge, then, puts a further constraint on the genetic explanation of knowledge: the explanation must provide for the possibility of the emergence of normative knowledge. Causal, reductionist explanations (e.g., in terms of neurophysiological causality) will not suffice. However, Piaget did not deny that states of knowledge and intelligence have a biological dimension: intelligence has a "dual nature," it is "both biological and logical" (Piaget 1976a, p. 3). Indeed, the major challenge is to explain how intelligence as a system of living and acting operations can be rooted in biology yet incessantly generate novelties and result in rigorous (i.e., logically necessary) and normative knowledge. For Piaget, this challenge can be met only when life is conceived as self-organization.

Self-Organization

It is generally accepted that psychological development has a biological basis. The question is how the relation between biology and psychological development should be conceptualized. Piaget used the concept of self-organization to characterize the relation between biology and psychological development (see Piaget 1971; see Boom 2009; Chapman 1992). At the biological level, self-organization is the process by which a system perpetually reconstitutes its processes (e.g., metabolic cycles) and elements (e.g., cells) in order to preserve its continuous functioning. This self-organizing activity is not something additional or external to the living system; rather, it pervades matter as active form and it arises when the reciprocal interactions between the elements or subsystem of the system lead to the formation of a higher-order system that regulates the elements or subsystems (Piaget 1971, p. 327 fn.). Living systems are self-organizing systems; in exchange processes with their environment, they spontaneously reproduce their organization.

The idea of self-organization can be traced back to Aristotle, and a brief excursion into how he explicated self-organization will help clarify its conceptual status. For Aristotle, form and matter are inseparable; matter is always already organized (Aristotle 1956, 412b, 4–25). Each thing has its substantial form or entelechy; psyche is the entelechy of living beings. Realized structure (entelecheia) of natural kinds must be viewed as the result of immanent processes (their energeia) (Aristotle 1971, 1046a:30, 1050a:22).

Psyche is best interpreted as self-organizing activity that preserves its own organization (Aristotle 1971, 1048b27; see Hübner 1999). Organic self-preservation has its goal inside itself, and this goal is achieved with the occurrence of organic self-preservation. Self-organizing activity preserves its organic body and the disposition that it exercises (Aristotle 1956, 417b2-7; 1971, 1048b18-34). Thus, psyche fulfills the body and preserves the body and the body's disposition to be psyche, and, because psyche is organic self-preservation, body and psyche possess the same being. As a consequence, Aristotle characterizes a living being by the fact that final cause and formal cause are fused together: the goal or telos is the form of the thing; the form of a living being is the continuous self-organizing activity; therefore, the telos of the living being is to preserve its form. A self-organizing system is like a physician healing himself (Aristotle 1970, 199b, 27–32). Machines, by contrast, are not self-organizing systems; their functioning does not result in their reconstitution, and formal cause and final cause are not fused together.

Piaget expanded on Aristotle by putting an evolutionary spin on the idea of self-organization. As he put it, "the very nature of life is constantly to overtake itself" (Piaget 1971, p. 362). Phylogenetically, the interaction between organism and environment leads to the emergence of higher-order self-regulatory processes, which, on the level of cognitive functioning, reflect the basic mechanisms of self-organization and, at the same time, constitute the most complex instruments for regulating the exchange with the environment (Piaget 1971). Moreover, cognitive functioning reflects reason in a double sense: it is the product of reason that is intrinsic to nature (i.e., in the logic of self-organization) and through cognitive functioning reason in nature becomes conscious of itself.

Thus, similar to Binet (Binet and Simon 1916, pp. 141, 153; see Bennour and Vonéche 2009), Piaget considered intelligence a biological adaptation. Self-organizing activity is the biological foundation and origin of intelligence, and cognitive processes are the outcome of and extend the processes of organic self-organization. Cognitive processes extend the processes of organic self-organization by using and adapting to new circumstances the different systems of organic self-regulation that can be found on the genetic, morphogenetic, physiological, and nervous levels. In support of this claim, Piaget (1971) describes many functional and structural analogies between cognitive and organic functioning. Central among these analogies is the triad of assimilation, accommodation, and scheme.

Assimilation, Accommodation, and Scheme

The complementary functions of assimilation and accommodation describe the general characteristics of the exchange between organism and environment (Piaget 1963, 1970, 1971). Assimilation is the aspect of an organism's activity wherein elements of the environment are integrated into the organism's preexisting organizational structures (i.e., the relations between elements). Accommodation, on the other hand, provides the material for the structuring activity of assimilation. Accommodation is the aspect of the activity wherein an organism's existing schemes are differentiated and modified in response to the environment. For example, a preexisting metabolic cycle assimilates particular nutrients by breaking them down into the elements that contribute to the continued functioning of the living system. The assimilatory cycle needs to be modified when the organism encounters a new nutrient (accommodation) (Piaget 1963). Assimilation and accommodation maintain the equilibrium between an organism and its environment.

Assimilation and accommodation at the psychological level extend the physiological interactions between the organism and the environment because their functioning no longer depends on the incorporation of material elements but now incorporates informational content (Piaget 1963, 1971). At the psychological level, schemes are characterized by what is repeatable in actions and thought processes (i.e., internalized actions). Assimilation refers to the incorporation of new information into already existing schemes, a process giving meaning to the content (Piaget 1963, 1985). For example, when a baby grasps a rattle, the rattle is assimilated to the grasping scheme and thereby attains the functional meaning of being "graspable." Assimilation always uses the existing psychological schemes; its functioning carries the history of the subject's interaction with the world into each particular act. For example, an infant who has differentiated various ways of interacting with the rattle will have different action potentialities available compared to an infant who has not.

Accommodation refers to the modification of existing schemes to account for particular features of the object or situation. Because schemes are structures with varying degrees of generality, applying them to particular situations always requires an adjustment or accommodation. Accommodation thus particularizes the general schemes, supplies them with specific content, and modifies them in doing so (e.g., the preexisting grasping scheme needs to be modified, becoming more specific to take into account the particular spatial position of the rattle).

Assimilation, accommodation, and scheme are inseparable. Assimilation is always a structuring activity because it involves integrating content into existing schemes; thus, structures do not exist independently of structuring activity: "Assimilation is hence the very functioning of the system of which organization is the structural aspect" (Piaget 1963, p. 410). At the same time, the incorporation of new elements leads to the modification of the scheme and thus to accommodation. Accommodation brings about adaptation to the environment, but this adaptation is always a function of the structuring activity of assimilation. The act of assimilating objects to schemes is rather complex because it involves affect, sensation, (internalized) motor elements, and perception (Piaget 1963, 1981).

Operative and Figurative Aspects of Intelligence

Closely related to the concepts of assimilation and accommodation are Piaget's (1969) notions of figurative and operative aspects of intelligence. The figurative aspect of intelligence includes the functions of perception, imitation, imagery, and (in part) language that are supplied by the accommodatory aspect of activity (Piaget 1969; Piaget and Inhelder 1971). The figurative aspect provides signifiers, which, in turn, bear on the "states" of reality and provide data on which the structuring activity of assimilation acts. For example, an infant may perceive a rattle and, assimilating it to an action scheme, she recognizes rattle as something that can be shaken (i.e., the sight of the rattle serves as a signifier of what can be done with it).

In contrast, the operative aspect of intelligence refers to the transforming and form-giving, or structuring, aspect of knowledge (Piaget and Inhelder 1971). It includes sensorimotor actions, internalized actions that are carried out mentally, and operations. Operations are internalized actions that have become reversible because they are organized in a structure such that each operation is coordinated and can be carried out simultaneously with an another operation that cancels it out (e.g., uniting and dissociating elements, adding and subtracting; Piaget 1976a). Piaget (1976a; Piaget et al. 1992) used different mathematical and logical tools to analyze the properties of the operational structures. Piaget (1973, 1974) was very clear that the subject is only aware of the outcome (i.e., his or her performance) of these structures, but not of the structures themselves.

The operative aspect of intelligence transforms subject-object relations by inserting the data provided by the figurative functions into increasingly complex structures. In other words, the operative activity of the human mind results in the construction of more and more complex relations (spatial, causal, logical, etc.) between person and world. The operative aspect of intelligence, then, is central to understanding the kinds of qualitative changes that occur in Piaget's account of cognitive development. The figurative aspect is an auxiliary of the operative aspect of intelligence in that it provides knowledge about states that are coordinated and transformed by operations. For example, the meaning of what the subject perceives is relative to his or her action tendencies, and perceptual activities (i.e., what the subject pays attention to) are dependent on the subject's operative development (Piaget 1969).

Equilibration

At each point in development, children are in a state of equilibrium with the environment, characterized by a particular balance of assimilation and accommodation. Development is a process that leads to increasingly more stable (complete and consistent) forms of equilibrium. Piaget (1985) termed this process equilibration. Equilibration must ensure two things: (1) It must always open up new possibilities (as life is creative); (2) it must conserve previous structures as substructures in new and elaborated structures. The second requirement is necessary to account for the fact that logico-mathematical knowledge does not become invalid with the construction of new knowledge (Piaget 1972a). Equilibration thus must reconcile the two contradictory tendencies of openness and closure of structures.

The theory of equilibration takes central place in Piaget's later work (Boom 2009), in which he focused in more detail on the specific processes involved in equilibration. Although Piaget identified several processes as playing an important role in equilibration, such as dialectics, contradiction, affirmation and negation, the generation of possibilities, and the process of becoming aware, his theory of equilibration remains unfinished (Campbell 2009; Piaget 1976b, 1980, 1987). Here we focus on the role of reflecting abstraction in equilibration, as reflecting abstraction is central to the construction of more powerful knowledge structures (Piaget 1971, 1985, 2001).

Reflecting abstraction is an elaborative process by which children discover the structural aspects of their cognitive activity (Piaget 2001). For instance, putting marbles, one after the other, in a receptacle is an action with several structural aspects, one of which is based on the creation of a serial order and another on the creation of a set with a growing number of elements. By becoming aware of the relations between and coordination of their actions, children abstract structure (the coordinatory or operative aspect of actions) from content and, in turn, project this structure to a higher cognitive level.

Piaget (1950a, 1972a, 2001) suggests that the general coordinations of actions (e.g., putting things together, establishing correspondences, ordering) are the source of logico-mathematical knowledge. For example, to understand the commutativity of addition ($3+2=5=2+3$), the child needs to put down objects in a different orders (e.g., first 3, then adding 2; after that 2, adding 3) and then realize that the total remains the same (i.e., the product of the actions is independent of the particular order in which the actions are executed; Piaget and Inhelder 1976). With the emergence of the semiotic function (see below), the knowledge abstracted from the coordination of actions becomes internalized, and the commutativity of addition can be deduced by mental operations.

The mechanism of reflecting abstraction then ensures that development has an intrinsic logic and proceeds by way of successively conceptualizing the structures or forms of knowledge underlying previous knowing levels (Piaget 1971, 2001). Thus, the form of stage n becomes the content of stage n + 1. With each new and higher stage, the forms become increasingly abstract. Through the mechanism of reflecting abstraction, then, development proceeds by way of successively conceptualizing and reconstructing the knowledge structures underlying previous knowing levels, thus ensuring the generativity and rigor of knowledge.

Constructivism

Piaget's way of conceptualizing intelligence and knowledge clashes with the way it is conceptualized by empiricism. Piaget himself was ardent in his opposition to empiricism (e.g., Piaget and Inhelder 1976). According to Piaget, empiricism conceives of human beings as passive, emphasizing sense perception, which provides copies of reality, and association as major sources of knowledge. Piaget argued that empiricists misconstrue the fundamentally active relation between subject and world as a passive, causal relation. Furthermore, Piaget (1970, 1972a, b) contended that the idea that knowledge is a copy of reality is flawed because there would be no way to evaluate the accuracy of such copies because they cannot be directly compared to reality itself. Rather, he was influenced by Kant's (1929) idea that objectivity is constituted by the subject. Kant argued that our intuition (i.e., sensibility) and understanding use a priori (i.e., independent of all experience) forms and categories, which are the condition of the possibility for experiencing objectivity. Piaget (1963, pp. 376–395) subscribes to the ordering and organizing function of the mind—indeed, this is implied in the notion of assimilation. However, Piaget believed that the forms and categories are not a priori or innate but rather undergo development as a result of the subject's interaction with the world—which is implied in the notion of accommodation.

As an alternative to empiricist and nativist interpretations of knowledge, Piaget proposed a constructivist interpretation, according to which knowledge is neither a simple recording of reality nor preformed, but an active construction that "at its origin, neither arises from objects nor from the subject, but from interactions—at first inextricable—between the subject and the object" (Piaget 1970, p. 704). It is in the course of these interactions that the subject becomes aware of herself as the (social and physical) world provides resistance to her projects, and she constructs an increasingly complex knowledge of the world as she coordinates her actions and operations (Piaget 1954).

At the psychological level, constructivism amounts to a pragmatist approach to knowledge because Piaget (1970, p. 704) emphasized action as the source of knowledge: "in order to know objects, the subject must act upon them, and therefore transform them: he must displace, connect, combine, take apart and reassemble them." Action is goal-directed and, at least early in life, aims at success and not truth; it is a lived and not a contemplative intelligence (Müller 2009). Action also transforms reality itself: "The construction of an electronic machine or a sputnik not only enriches our knowledge of reality, it also enriches reality itself, which until then did not include such objects. This creative nature of action is central" (Piaget and Inhelder 1976, p. 33).

Constructivism combines genesis (empiricism) and structuralism (nativism): every genesis originates from one knowledge structure and results in another structure, and, conversely, every structure has a genesis (Piaget 1967). We now turn to the stages defined by the succession of structures.

Stages in the Development of Intelligence

In standard psychology textbooks (e.g., Berk 2012), Piaget is typically portrayed as a stage theorist who claimed that stages are general structures that define a child's behavior in each area of cognitive functioning and that age is a criterion for stage. Consequently, it is argued that Piaget's theory is flawed because empirical evidence shows that at any point in development, children's behavior is heterogeneous and not homogeneous (e.g., they may reason at a preoperational level in one conservation task, and at a concrete-operational level in another) and that particular stages emerge earlier than Piaget would predict.

This portrayal of Piaget's stage theory is utterly incorrect (Chapman 1988; Smith 1993). Piaget did not claim that stages are characterized by homogeneity, and, in fact, Piaget often made the opposite point that variability should be expected (Chapman 1988). Furthermore, variability in children's performance on structurally similar tasks is entirely consistent with the basis of Piaget's grounding assumption that thought originates in action. Based on this assumption, cognitive structures should, at first, be context and content specific. That is, cognitive structures cannot be separated from their content, and although structures involving different content (e.g., number and volume), may be of the same logical form, they develop independently in a functional sense through the child's activity with these different areas of content.

Stages are also not defined in terms of age. Rather, they are defined in terms of performance on particular tasks that Piaget analyzed in terms of the operations and structure they require. He acknowledged that the age of acquisition of operations is highly variable and influenced by the amount of cognitive stimulation. Furthermore, central to Piaget was not the age at which the stages emerge but the mechanisms involved in stage transitions. Each stage is a temporary equilibrium in the process of equilibration (Piaget 1985, p. 139). Higher stages are in a better equilibrium; they are characterized by a more complex understanding of the world (greater spatiotemporal distance) and more mobile operative structures. Because the stages build on each other, they constitute an invariant sequence. But there is no fixed, predetermined end point to the development of intelligence because a new stage always opens up new possibilities of interacting with the world, which may lead to further development. We next briefly describe the main characteristics of each stage (see Chapman 1988).

Sensorimotor Stage Piaget (1963; see Müller 2009) termed the developmental period during approximately the first 18 months of life sensorimotor intelligence. It plays a key role in bridging the gulf between the biological level of functioning and rational thought. Sensorimotor intelligence is a practical, embodied intelligence on the basis of which infants interact with the world through perception–action cycles. At the sensorimotor stage, meaning is originally embedded in unreflective activities; objects have a functional, practical meaning, they are things at hand, utensils for practical use or manipulation. Infants employ action schemes like sucking, pushing, hitting, and grasping to explore and manipulate the world. At the outset, the newborn has no self-consciousness and no clear awareness of what effects she herself produces through actions on the world and what effects occur independently of her actions. By coordinating her actions and applying them in the social domain (imitation), the infant gradually learns to distinguish between self, other persons, and world.

Piaget traced the process of differentiation and coordination of action schemes through several sensorimotor substages. Drawing on Claparède's (1917) suggestion that intelligence is an adaptation to new circumstances, Piaget highlighted the transition between sensorimotor substages III and IV. During sensorimotor substage III (approximately 4–8 months), children use secondary circular reactions (i.e., actions that focus on the effects they produce in their world) to interact with the world. Essentially, secondary circular reactions aim at reproducing the effect by repeating the action that generated this effect in the first place. For example, Piaget's daughter Lucienne moved her legs vigorously, thereby shaking her bassinet. The movement made the dolls swing that were hanging from the hood. Lucienne looked at the dolls, smiled, and repeated the movement (Piaget 1963, Obs. 94). At sensorimotor substage VI (approximately 8–12 months), by contrast, infants construct hierarchical relations between secondary circular reactions by subordinating one action as a means (e.g., removing an obstacle) to another action as an end (e.g., grasping the rattle). The coordination of secondary schemes differs from the behaviors displayed at the previous substage in two ways (Piaget 1963, p. 229). First, whereas secondary circular reactions simply tried to reproduce an interesting event, the coordination of secondary circular reactions becomes necessary when infants in pursuit of their goals encounter an obstacle that requires them to accommodate existing schemes to a new situation. Second, whereas secondary circular reactions lead to the differentiation between means and ends only after the fact, means and ends are differentiated in substage IV from the outset. At substage IV, then, children coordinate two independent schemes, the scheme assigning an end to the action (e.g., grasping the rattle) and the scheme used as a means (e.g., removing the obstacle). Because the behavior at substage IV requires an adaptation to a new situation, Piaget (1963, p. 228) terms means–end coordination a "true act of intelligence" and "the beginning of intelligent action."

The coordination and differentiation between actions result in the construction of increasingly complex relations between objects—"the objectivization of reality" (Piaget and Inhelder 1976, p. 32)—as reflected in the development of such basic categories as space, time, causality, and object (Piaget 1954). For example, in order to remove a cushion that is placed in front of an object, the child must realize for herself that the cushion, in fact, is placed in front of the object (space), that she must remove it before grasping the object (temporal series), that the object behind the cushion still exists (object permanence), and that in order to remove the cushion she must grasp it (spatialized and objectified causality).

The sensorimotor period ends with the emergence of symbol representations, which allow infants to transcend the immediate here and now. At the completion of the sensorimotor stage, for the infant, his own action is no longer the whole of reality and instead now becomes "one object among others in a space containing them all; and actions are related together through being coordinated by a subject who begins to be aware of himself as the source of actions" (Piaget 1972a, pp. 21–22).

Preoperational Stage The emergence of the symbolic or, as Piaget also termed it, semiotic function marks the onset of the preoperational stage, which extends from about 2 to about 7 years (Piaget and Inhelder 1969). The semiotic function underlies children's abilities to engage in a number of different activities, such as deferred imitation (i.e., imitation in the absence of the model), pretend play, drawing, psychological functions based on mental images (e.g., recall memory), and language. These activities are practiced and refined during the first substage of this stage, the level of preconceptual thought (approximately 2–4 years of age). At the same time, preoperational thought is characterized by profound cognitive limitations. For example, although preconceptual thought is no longer tied to particular objects or events (the here and now), it fails to distinguish between individual members of a concept and the generality of a concept. To illustrate, when Piaget's daughter Jacqueline was 31 months old, she cried upon seeing a slug, "There it is!" When she saw another slug a few yards further she said, "There's the slug again" (Piaget 1962). At this substage, concepts thus remain midway between the generality of the concept and the individuality of elements composing it. On the one hand, there is no concept of a general class; on the other hand, particular objects have less individuality and easily lose their identity.

At the second substage of preoperational thought—termed intuitive thought—symbolic representational schemes become increasingly coordinated, and children become capable of relating two such schemes to each other by means of an unidirectional logical relation (Piaget 1970). For example, in comparing the liquid in two differently shaped containers, children may use height in order to infer the amount of liquid, but ignore the width of the container. Intuitive thought thus remains centered on one dimension (e.g., height) and fails to establish bidirectional relations between dimensions (Piaget et al. 1977).

Concrete Operational Stage During the concrete-operational stage, which emerges around 6–7 years, operations (i.e., internalized actions such as putting like objects together, putting objects in one-to-one correspondence) become coordinated and integrated into logical systems (see Bibok et al. 2009). As a result, children no longer center on one aspect of a situation, and they can mentally reverse transformations that have occurred in reality. The coordination of operations into systems also leads to the emergence of logical necessity (Piaget 1976a).

Piaget devised a variety of conservation tasks to assess concrete-operational thought. Conservation refers to the understanding that a whole exists as a quantitative invariant and therefore remains intact despite the quantitative rearrangement of its parts (Piaget and Inhelder 1974). For example, the number of objects in a set does not change by rearranging them (e.g., spreading them out). To understand that the quantity has not changed, children need to coordinate transformations in two dimensions (density of objects, length of row of objects). An operative understanding of conservation is logical in nature, and it is not given by empirical observation of transformations.

Another concept that children understand at the concrete-operational level is class inclusion (Piaget and Inhelder 1969; Piaget 1980). A typical class inclusion task requires children to compare the number of objects in the including or superordinate class with the number of objects in the most numerous of two of its subclasses. For example, given 12 daisies and 4 roses, children are asked, "Are there more daisies or more flowers?" A correct answer requires that children conserve the including class (B) while making the quantitative comparison between it and the included class (A). Although this may sound simple enough, such a comparison actually involves a multistep process in which children must not only be able to construct the including class but also be able to reverse this affirmative operation by properly decomposing it. The first step involves being able to combine two subclasses to form a superordinate class, or A (daisies) + A' (roses) = B (flowers). The second step involves performing the inverse (negative) operation associated with this combination of subclasses. This entails subtracting each subclass from the superordinate class such that A = B − A' and A' = B − A. The inverse operation, thus, implies that children construct each subclass through negation under the including class. Piaget termed this type of negation partial because it is applied to a part of a larger whole. Through partial negation children realize that the subclass A is an autonomous whole, which enables them to recognize that there are some B's that are not A's (e.g., there are some flowers that are not daisies) and that, therefore, there are more B's than A's. The different operations required by class inclusion provide an example of an operational structure (Piaget 1976a).

Formal Operational Stage The last stage of cognitive development described by Piaget emerges during adolescence (Inhelder and Piaget 1958; see Moshman 2009). Piaget and his collaborator Bärbel Inhelder studied formal operations by presenting children and adolescents with concrete material (e.g., different weights, strings of different length) to be manipulated in order to discover scientific laws or the cause of a result from several possible factors (e.g., which factor—weight, length of string, height of dropping point, force of push—determines the frequency of the pendulum's oscillation). These studies revealed that children approached scientific problems in a qualitatively different way than adolescents. Although children were capable of classifying and cross-classifying the independent variables, of properly ordering magnitudes of the independent variable along one dimension, and of putting these seriations into correspondence with their effects on the dependent variable, they failed to separate the involved variables by varying only one variable and holding all others constant. As a result, these children did not supply adequate proof for their statements. By contrast, from the outset, adolescents formulated hypotheses and derived conclusions from these hypotheses. They then proceeded to test these hypotheses by systematically controlling all variables except the one under investigation. Thanks to their systematic experimental approach, adolescents excluded hypotheses that were contradicted by observations and converged on the hypothesis that was actually true.

For Piaget, the difference between children's and adolescents' approaches to these problems suggested the reversal of the direction between reality and possibility: whereas in the concrete-operational stage, possibility remains an extension of reality, in the formal-operational stage, reality is subordinated to possibility. Adolescents are capable of thinking hypothetico-deductively by drawing necessary conclusions from truths that are considered merely possible.

Semiotic Function and Intelligence

Piaget (1963; Piaget and Inhelder 1971) held that consciousness is always based on signs or, better, signifiers. Signifiers are items that convey meaning. At the sensorimotor level, signifiers are not yet differentiated from their referent (signifieds). Signifiers at this level are termed indications. An indication is an "objective aspect of external reality" (Piaget 1963, p. 193), "a perceptible fact which announces the presence of an object or the imminence of an event (the door which opens and announces a person)" (Piaget 1963, pp. 191–192). Signifieds at this level are sensorimotor schemes that confer meaning on the elements interacted with.

At the end of the sensorimotor stage, the coordination and differentiation of schemes culminate in the emergence of signifiers that are differentiated from their signifieds. Piaget (Piaget and Inhelder 1969, 1971) termed a system of such signifiers the semiotic function. The semiotic function subsumes both symbols and signs. Piaget defined symbols such as mental images as signifiers (i.e., they resemble the things signified) and signs, such as words, as arbitrary and conventional signifiers. The semiotic function makes it possible for children to form mental representations and to think about absent objects as well as past, future, and even fictitious events. It also increases the speed of processing because it makes it possible to imagine at the same time the successive phases of an action. Finally, it opens up the possibility of reflecting on and understanding the reasons why some actions are successful and others not (Piaget 1954).

During the preoperational period, children use symbols in symbolic play (e.g., a toy cup stands for a real cup), deferred imitation (e.g., imitating an action of an absent model), and drawing (Piaget 1962; Piaget and Inhelder 1971). Piaget believed that particularly young children need to rely on the use of individualized and personal systems of symbols (Piaget and Inhelder 1971). This is because personal symbols make fewer processing demands than language which is based on collective and arbitrary signs. Piaget recognized that language is essential to socialization, which, in turn, modifies action and behavior. Verbal exchange between individuals allows children to share ideas, and the resulting "collective concepts" reinforce individual thinking (Piaget 1995). Being more mobile than symbols, language also makes a unique contribution to the mobility of thought.

At the same time, neither language nor symbols are the source of the forms of thought found at the concrete- and formal-operational stages. According to Piaget (1970), these forms of thought are grounded in the practical coordination of actions (e.g., grouping objects, seriating objects) at the sensorimotor stage. The semiotic function, and particularly language, is necessary for the internalization of actions (i.e., without the semiotic function, operations would have to be executed as successive actions and could not be condensed into a simultaneous whole), but it is not sufficient to explain logical thought. In sum, Piaget considered the semiotic function only a tool used by and dependent on the operative aspect of intelligence (Piaget and Inhelder 1969, 1971).

Affectivity and Intelligence

There is a long tradition of treating intelligence and emotion as distinct. Even in present-day psychology, IQ and EQ are thought of as separate (or even opposing) constructs (Goleman 1990).

In contrast to dualistic conception, Piaget (1981; see Sokol and Hammond 2009) believed that all behaviors involve an affective aspect and a cognitive aspect. The affective aspect is responsible for motivating the organism's interaction with the environment by assigning a value or goal to the behavior. However, achieving a particular end can involve a number of different paths. It is the cognitive aspect of behavior that structures such paths and thus the relation between the individual and the environment. In other words, affect provides the values and ends for actions, whereas cognitive functions are the means for achieving the ends (see Binet and Simon 1916 p. 142).

To illustrate that any intelligent act contains both affective and cognitive contributions, take the following sensorimotor action: a child reaches for a toy by pulling on the blanket under the toy. This act has an affective component. In fact, two types of affectivity are involved in this act: synchronic affectivity (in the moment) and diachronic affectivity (over time). First, the child evaluates his current actions with feelings of success and failure (synchronic affectivity), and second, the child's evaluations of the situation involve a system of values that he has developed over time, engaging his interest in obtaining the toy (diachronic affectivity). These affective components regulate the cognitive component of the act that facilitated obtaining the object by pulling on the blanket. Thus, affect provides direction for intelligence, first by regulating interest and effort and, second, by assigning value to solutions sought. As such, for Piaget, affect and intelligence are inseparable, and Piaget (1981) often underscored the role of affectivity in intellectual growth.

Social Interaction and Intelligence

Piaget is often accused of failing to address the role of social interaction in development. This, however, is not the case (see Kitchener 2009). Piaget was by no means oblivious to the role of the social in development, as attested by, for example, his statement that "human intelligence is subject to the action of social life at all levels of development from the first to the last day of life" (Piaget 1995, p. 278). In his work, Piaget struggled with the fundamental epistemological question: "Is it the individual as such or is it the social group that constitutes the motor or, if you prefer, the 'context' of intellectual evolution?" (Piaget 1995, p. 215). Piaget contrasted his own solution to this question with theoretical positions which suggest that rationality is derived either from the individual or the collective. By reducing the social to the aggregation of ready-made individual consciousnesses, individualism provides an atomistic explanation of the social and rationality. Collectivism, on the other hand, considers the social as a whole that cannot be derived from an additive composition of individuals. Rather, the collective whole is characterized by emergent, novel properties and structures, and it modifies its members (i.e., individual persons; see Piaget 1995).

Piaget criticized both individualism and collectivism and proposed an interactive relational position as an alternative explanation of the role of social interaction in intellectual development. According to the interactive relational position, "there are neither individuals as such nor society as such. There are just interindividual relations" (Piaget 1995, p. 210). These relations between individuals are primary and "constantly modify individual consciousnesses themselves" (Piaget 1995, p. 136). The interactive relational point of view leads to a more fine-grained analysis of specific social relationships and their implications for development. Piaget describes two extreme types of social interaction: constraint and cooperation. Whereas constraint involves the imposition of authority and group traditions on the individual, cooperative interactions are based on reciprocity and equality. In his early work, Piaget (1932, 1995) argued that cooperative relations among equals are necessary for the development of rationality and autonomous morality; by contrast, relations of unilateral respect in which one individual has to submit to another individual's authority impede the development of morality and rationality.

The upshot of the interactive relational view is that because individuals must coordinate their actions vis-à-vis the world, "[i]ndividual operations and cooperations form one inseparable whole in such a way that the laws of the general coordination of actions are, in their functional nucleus, common to inter- and intraindividual actions and operations" (Piaget 1971, p. 98). Individual operations and cooperations are subject to the same kind of combinations and transformations as actions and operations, thus the question of whether rationality is essentially social or individual becomes moot:

> To wonder whether it is intrapersonal operations that engender interpersonal co-operations or vice versa is analogous to wondering what came first, the chicken or the egg … The internal operations of the individual and the interpersonal coordination of points of view constitute a single and the same reality, at once intellectual and social. (Piaget 1995, pp. 294, 307)

For that reason, social interactions are subject to and regulated by the same equilibration processes as intraindividual actions and operations.

Conclusion

In this chapter, we described, in broad strokes, Piaget's theory of intelligence. We showed that Piaget defined intelligence as the cognitive organization of an organism. More specifically, Piaget argued that intelligence can be defined functionally as resulting in increasing spatiotemporal distances between subject and world and structurally in terms of a sequence of stages that move toward increasing reversibility. We showed how Piaget's conception of intelligence is rooted in his larger epistemological framework, and we described major features of this framework.

Even though many aspects of Piaget's theory have been heavily criticized (Lourenço and Machado 1996), we believe that the way in which he conceptualized the relations between affectivity, symbols, social interaction, and intelligence was original and provides a fruitful direction for overcoming sterile dichotomies. Furthermore, we think that three features of his theory are essential to any comprehensive and coherent theory of intelligence. First, theories of intelligence must address the biological dimension of intelligence. Elegantly, Piaget's insight into self-organization grounded his conception of intelligence in the very feature of life itself. Second, intelligence is not passive, not a process triggered by an input and, in turn, triggering some sort of output. Theories of intelligence must capture the fact that human beings are active and transform through their actions the world. Intelligence is not just comprised of a set of theoretical abilities; it includes, and is grounded in, practical skills. Third, intelligence has a normative dimension. This normative dimension includes values, moral norms, and logical necessity (Smith 1993, 2009). The normative dimension, which may be unique to humans, has been recalcitrant to reductionist explanations. We submit that a successful theory of intelligence will be based on the valuable insights provided by Piaget's theory, that is, modern intelligence theories must be grounded in biology, acknowledge the active nature of intelligence and the role of practical intelligence, and capture the normative dimension of knowledge.

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11 Alfred Binet and the Children of Paris

Amber Esping and Jonathan A. Plucker

Alfred Binet was born in 1857 to a wealthy but troubled French family. His father, a physician, and his mother, an amateur artist, divorced when he was a child, and he grew up in his mother's household. Family resources afforded him an excellent private school education in Nice and later Paris. He distinguished himself in French composition, but his academic record was otherwise unremarkable (Siegler 1992; Wolf 1964). Binet's career path appeared desultory and unpromising at first. In 1878, he earned a law degree from the University of Paris, but never expressed any real interest in the field. He would later call law "a career for those without any [yet] chosen vocation" (Binet 1904a, p. 14). Next he attempted a medical degree at the Sorbonne in Paris, but he was profoundly distressed by the trauma and gore he witnessed in the operating room, to which he may have been especially sensitive owing to a childhood experience in which his father forced him to touch a cadaver.[1] He suffered an emotional collapse and dropped out of medical school at age 22 (Fancher 1985).

Following his psychological breakdown, Binet spent considerable time resting and reading among the peaceful stacks of the National Library of France in Paris. While browsing books on psychology, he discovered some ideas in which he could at last become genuinely and passionately invested. He first became intrigued by psychophysical experiments involving tests of two-point sensation thresholds, and he replicated some of the published experiments using himself and some friends as subjects. He concluded from his own results that extant theories about sensation thresholds should be modified, and he published a paper outlining his suggested corrections (Binet 1880). The article was well written and cogently argued, but unfortunately it was also fueled by naïve enthusiasm. The ideas Binet put forth as his own had in fact already been published—in much more sophisticated form—by a respected Belgian physiologist by the name of Joseph Delboeuf (1831–1896). Delboeuf responded by publishing a humiliating critique of Binet's article (Delboeuf 1880; see also Fancher 1985; Wolf 1964).

Undeterred, Binet continued to read about psychology and to publish articles independently,

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[1] Binet told the story of touching the cadaver in 1911, indicating that this distressing experience had happened to one of his "friends." Compelling circumstantial evidence suggests that he was really talking about himself (see Wolf 1964, pp. 762–763).

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leading one biographer to dub him a "library psychologist" (Siegler 1992, p.180). He was most interested in English associationists like John Stuart Mill (1806–1873), Herbert Spencer (1820–1903), and Alexander Bain (1818–1903), but he was also influenced by Hippolyte Taine's (1828–1893) philosophical treatise *On Intelligence* (1870/1872) and Théodule-Armand Ribot's (1839–1916) treatments of English and German psychology (Foschi and Cicciola 2006). Mill was Binet's particular favorite, and he would later refer to him as "my only master in psychology" (Binet 1903, p. 68). Binet's second publication forwarded Mills' associationism as an all-encompassing explanation for the operations of the intellect (Binet 1883), but here again he was overconfident. Associationism was already beginning to lose its cachet, and prominent psychologists were routinely acknowledging its inability to account for motivational or unconscious influences (Fancher 1985). Binet eventually realized these deficiencies of associationism, but he never abandoned it completely. Indeed, his associationist roots would later be evident in his greatest achievement, the Binet-Simon Intelligence Scale (1905).

In 1883 Binet's independent means made it possible for him to volunteer his time assisting the eminent neurologist Jean-Martin Charcot (1825–1893) with his research at the Salpêtrière Hospital in Paris. Charcot was interested in hysteria, a baffling syndrome in which female patients experienced paralysis, loss of sensation, seizures, and memory loss, with no apparent neurological cause. Whereas some physicians attributed these cases to malingering, Charcot believed that the patients experienced these symptoms as real (Fancher 1985). Charcot's associated interest in hypnosis grew from the finding that some of the same "symptoms"—paralysis, amnesia, dramatic fits, and so on—could be induced through hypnotic suggestion. Therefore, the study of hypnosis offered promise in understanding the underlying causes of hysteria (Fancher 1985).

Binet assisted Charcot in hypnosis studies of hysterical patients. One particular responsibility was Blanche Witman, an intense and melodramatic young woman who was known in the wards as "The Queen of Hysterics." Ms. Witman could be relied upon to follow the three-stage hypnotic pattern of lethargy, catalepsy, and somnambulism that Charcot believed was definitive of major hypnotism. Charcot and Binet saw this easy susceptibility to hypnotic states and consistent pattern of responses as an indication of her underlying hysterical disorder. Indeed, Charcot believed generally that susceptibility to hypnosis was an indication of an underlying hysteria. This conclusion would later turn out to be incorrect (Fancher 1985).

In a series of related experiments with Ms. Witman, Binet and another of Charcot's assistants, Dr. Charles Féré (1852–1907), discovered that they could reverse or transfer Ms. Witman's behaviors under hypnosis simply by reversing the polarity of a large horseshoe magnet. For example, if Ms. Witman seemed to be paralyzed on her right side, they could transfer the paralysis to the left by reversing the magnet. They found that they could transform the expression of an emotion, such as sobbing, to its inverse (laughing) through the same mechanism. Binet and Féré were fully convinced by Charcot that deeply hypnotized people were not aware of their surroundings, so they did not consider the possibility that their patient might be attending to the magnet or related experimenter cues. In a series of articles (Binet and Féré 1885a, b, c), they attributed the magnet findings to the existence of complementary human emotions, akin to complementary colors which produce white or black when mixed (Fancher 1985).

Unfortunately for Binet, his first critic, Joseph Delboeuf, also had a side interest in hypnosis. Delboeuf respected Charcot and was ready to accept his theory of major hypnosis, but he was skeptical of the magnet findings—especially so when he saw Binet was one of the paper authors (Fancher 1985). Curious, Delboeuf visited the Salpêtrière hospital and saw immediately that Ms. Witman was aware of the magnet and was undoubtedly yielding—consciously or unconsciously—to the desires of Féré with whom she seemed to have a particular rapport. When Delboeuf undertook the same experiments under more carefully controlled conditions, he discovered that both the magnet findings and Charcot's theory of major hypnosis were invalid (see Delboeuf 1886). Binet was at first reluctant to accept Delboeuf's evidence, and a heated public exchange ensued (Binet and Delboeuf 1886). However, Binet eventually acknowledged the "loopholes for error" which had "pervert[ed]" interpretation of his study results (Binet 1896/1977, p. 76). This proved to be an essential lesson for Binet, and he was ever afterwards aware that psychological tests will always contain some degree of error. His willingness to acknowledge and work within the constraints of this fact has been called by one scholar "[perhaps] Binet's greatest contribution" to intelligence testing (Kaufman 2009, p. 22).

Following this major career setback, Binet left the Salpêtrière, and it took more than a year to find another position. Fancher (1985, p. 57) notes that under the circumstances, it is not surprising that "prospective employers did not come flocking to his door." However, he eventually connected with the director of the new Laboratory of Physiological Psychology at the Sorbonne, and he willingly accepted Binet's offer to work there, as he had done at the Salpêtrière, without compensation. He served there as a researcher and assistant director and ascended to become the laboratory's director in 1894. He held this unpaid position until he died in 1911 (Fancher 1985; Siegler 1992.)

Binet's early career may be characterized as a series of productive false starts. He made mistakes, to be sure, but in the process he gained skills and dispositions that would prove enormously beneficial in his future intelligence work. From the hypnosis debacle, he learned the importance of careful attention to experimental controls. But he also learned to appreciate the advantages of the detailed case study approach to research. This distinguished him from contemporaries like Francis Galton (1822–1911) and James McKeen Cattell (1860–1944), who favored generalizations based on large sample sizes. This appreciation of the uniqueness of individuals convinced Binet that measuring psychological variables was a far more complex and nuanced process than other intelligence researchers had so far been willing to acknowledge (Fancher 1985). His time at the Salpêtrière also allowed Binet's passive associationist psychology to mature into a sophisticated theory that recognized the active role of human attention, as well as the importance of innate and hereditary factors in determining one's makeup (Fancher 1985).

Binet and Experimental Child Psychology

Binet's curiosity was unbounded, and he produced many other significant acts of scholarship while working with Charcot at the Salpêtrière. His publications during this time included three books and more than 20 articles exploring a wide variety of subjects. Among these were the psychic life of microorganisms (Binet 1887a), sexual fetishes (Binet 1887b), and the nature of human consciousness (Binet 1890a). He also developed an interest in the natural sciences, eventually earning a Ph.D. for a dissertation on the anatomy and physiology of the subintestinal nervous systems of insects (Binet 1894). The birth of his daughters, Madeleine (b. 1885) and Alice (b. 1887), provided an avenue to study child psychology, and in 1890 he published three articles describing experiments he conducted using his girls and their friends as subjects (Binet 1890b, c, d). This emerging interest in the psychology of children evolved into Binet's new career as an experimental child psychologist (Fancher 1985).

Binet derived his first experiments with Madeleine and Alice from Galton and Cattell's psychophysical tests of reaction times and sensory acuity, which up to this point in history represented the state of the art in intellectual testing. He noted that on average, his young subjects reacted to stimuli much more slowly than did adults but also that they were far less consistent in their performances; a child's reaction time might be on par with the typical adult in one trial and substantially slower in the next. Binet deduced that the salient difference between adults and children, then, was not really the reaction times but rather the children's limited ability to sustain attention during the trials. This insight about the importance of attention proved to be fundamental to the eventual development of his intelligence scale (Fancher 1985).

Binet's psychophysical tests of color perception also yielded interesting results. Child subjects were much slower than adults in naming colors, and this outcome might have been used to support the hypothesis that children had less developed sensory acuity than adults. However, when Binet asked the child subjects to match colors, they were nearly as fast as the typical adult. From this Binet concluded that seeming adult-child differences in color perception were in actuality methodological artifacts resulting from differences in language development—the kids could see the differences; they just could not *say* them fast enough. Binet eventually lost faith in psychophysical testing as a reliable and valid measure of intellectual ability and determined that more complex, language-based tasks were needed to discriminate child from adult intellectual capacity (Fancher 1985).

Binet advanced his understanding of the importance of language development by asking his children and their friends to define common words. He discovered that children typically responded by providing concrete, functional examples of how the items were used rather than the abstract dictionary-type definitions most adults provided. For example, a knife was defined as "to cut meat." The definition of snail was "squash it." From this adult-child difference, Binet concluded that the ability to think in abstract terms must somehow be important to the development of human intelligence (Binet 1890b; see also Fancher 1985). He continued to study his children, retaining some of the Galtonian psychophysical tasks and also including tests of memory, judgment, imagination, and inkblot interpretation, as well as qualitative impressions about their temperaments and personalities. He published these results in book form in 1903 (Binet 1903).

Other aspects of human intellectual development also caught Binet's attention during these early years at the Sorbonne. He expanded his subject pool to include children in the local schools, undertaking studies of memory and suggestibility. He discovered that both accuracy of children's memories and their ability to resist the influence of experimenter suggestion improved with age (Binet 1900). He also initiated several in-depth case studies of people with extraordinary abilities and accomplishments, such as chess prodigies and mathematical wizards (Binet and Henneguy 1894) and eminent French authors (Binet and Passy 1895). From these, he determined some unanticipated facts about the human intellect. First, there are many ways of becoming extraordinary; the great writers and math and chess prodigies approached their cognitive tasks in a variety of ways. Second, for the most part, these extraordinary individuals were quite ordinary in domains other than one particular narrow area of excellence. Binet recognized these findings as important evidence of the complexity and heterogeneity of intellectual operations (Fancher 1985). The psychophysical testing that had dominated the field to this point would never be able to tease out these kinds of nuances. New methods for testing individual differences in intellectual functioning had to be developed.

Binet and Individual Psychology

However valuable the in-depth case analyses Binet cut his teeth on, he also recognized that these long investigations were not always practical. Psychologists needed to be able to compare intellectual functioning quickly along some standard dimensions, preferably in one sitting. His prior research had illuminated the vulnerabilities of psychophysical testing, so the relatively fast methods he sought would have to test higher-order cognitive processes. Binet and his research assistant, Victor Henri (1872–1940), identified 10 candidate variables for measurement: (1) memory, (2) imagery, (3) imagination, (4) attention, (5) comprehension, (6) suggestibility, (7) a esthetic sentiment, (8) moral sentiment, (9) muscular strength and willpower, and (10) motor ability and hand-eye coordination. The last two variables resonated with earlier psychophysical testing approaches, but as conceived they were more complex than standard tasks of that kind. The other eight variables were refreshingly original in flavor (Fancher 1985). Binet named this new approach "Individual Psychology" (Binet & Henri, 1986).

In 1899, a young medical student named Théodore Simon (1873–1961) contacted Binet and requested an opportunity to work with him. Binet did not need another assistant, and he was inclined to refuse the offer. However, Simon had recently obtained a medical internship working with approximately 300 abnormal children[2] at the Perray-Vaucluse asylum, near Paris, and Binet found the opportunity to apply Individual Psychology with this special population very attractive. He accepted the offer of help and trained Simon to use his testing techniques.

Simon returned to Perray-Vaucluse and spent the next several months engaged in psychological testing. These data would later become his doctoral thesis in medicine (Wolf 1961). Unfortunately, the results of Binet's Individual Psychology research program were largely disappointing. In a 1904 paper, Binet reported that they had failed to produce a valid and discriminating psychological test that could be administered in a short period of time. The in-depth case study, it seemed to him, was still the most promising approach to individual psychology (Binet 1904b; see also Fancher 1985). However, in short order Binet would be offered a challenge that would change his mind.

Binet Invents the Intelligence Test

By the early part of the twentieth century, French national laws had begun mandating public school education for all children, including children with mental disabilities, who had previously been excluded entirely or permitted to drop out early from schooling. In 1904, officials of the French government asked Binet to join a distinguished commission of experts who could provide insight and leadership regarding the education of these special cases. Binet's Individual Psychology research, his publication record, and his particular experience with Simon's institutionalized children uniquely qualified him for this undertaking. He immediately recognized the need for a diagnostic system that could identify those children who could benefit from special education classes and, just as important, prevent intellectually normal children from being misdiagnosed (Binet and Simon 1905a). One year later, he had one: The Binet-Simon Scale, the world's first modern intelligence test (Binet and Simon 1905b). In a 1909 book, Binet described the enthusiasm with which he approached this work:

> There is nothing like necessity to generate new ideas. We undoubtedly would have retained the status quo…if a matter of true social interest three years ago, had not made it mandatory for us to measure intelligence by the psychological method. It had been decided to try to organize some special classes for abnormal children. Before these children could be educated, they had to be selected. How could this be done?…It was under these circumstances that our devoted collaborator, Dr. Simon, and I formulated a plan for measuring intelligence. (Binet 1909/1973, pp. 104–105)

The definition of "intelligence" is a difficult thing to pin down even in the twenty-first century (Plucker and Esping 2014), and Binet and Simon were working from scratch. They began by looking for evidence of what might now be termed "face validity"—that is, by recruiting groups of children who had previously been identified by experts as being obviously intellectually normal or clearly subnormal in their intellectual functioning. Drawing on their earlier work in Individual Psychology, Binet and Simon administered a variety of tests to both groups, with the expectation that some of these tests might plainly differentiate normal from subnormal children. In choosing their tasks, the researchers were particularly careful to avoid items that might rely heavily on formal education, as they wanted their tests to show evidence of psychological functioning, not educational attainment. This remains an essential goal of intelligence testing to the

[2]The language used to describe intellectual and developmental disability in the late nineteenth and early twentieth centuries included the (now offensive) terms abnormal and feebleminded and the clinical labels moron, imbecile, and idiot. Binet preferred the term *débiles* ("weak ones"). The person-first language considered respectful in the twenty-first century (e.g., "persons with intellectual disabilities") was unheard of.

present day (Kaufman 2009). As one means of accessing higher-order processes, they chose to include some questions about typical life within the French cultural context. They believed that it was safe to assume that even poor children of normal intelligence would have reasonable familiarity with this kind of information (Fancher 1985).

Binet and Simon's first attempts at differentiating intellectually normal from subnormal children were unsuccessful. There were able to find important differences in average performance on the tasks, but they failed to find any set of items that only the normal children could solve. There was always overlap, with some normal children failing tests that some subnormal children passed. The "aha!" moment came when the researchers recognized one essential difference between the two groups: the normal children were able to respond to the tasks correctly at an earlier age than the other group. It was critical to take age into consideration when scoring (Fancher 1985).

Armed with this insight, the researchers created a series of tasks of increasing complexity. Some of the simplest test items assessed whether or not a child could follow a lighted match with his eyes, take a candy out of a wrapper, or shake hands with the examiner. Slightly harder tasks required children to point to various named body parts, repeat back a series of 3 digits, repeat from memory a 15-word sentence, and define words like *house, fork*, and *mama*. More difficult test items required children to state the difference between pairs of things, reproduce drawings from memory, and construct sentences from three given words such as *Paris*, *gutter*, and *fortune*. Some of the hardest items asked children to repeat back seven random digits, find three rhymes for the French word *obéissance*, state the difference between abstract concepts like *sad* and *bored*, and answer questions such as, "My neighbor has been receiving strange visitors. He has received in turn a doctor, a lawyer, and then a priest. What is taking place?" (Fancher 1985; Kaufman 2009).

The scale was revised in 1908 and 1911. The newer versions were developed with larger sample sizes, greater age, and socioeconomic ranges, and items calibrated such that they could be "located" at ages where typical children started to complete them successfully (Binet 1911; Binet and Simon 1908). For example, a 10-year-old child who completed all the tasks usually passed by 10-year-olds—but nothing beyond—would have a mental level that exactly matched his or her chronological age, 10.0. Children who attained a mental level 2 or more years behind their chronological age—e.g., a 10-year-old child with a mental level of 8—were generally diagnosed as being mentally subnormal, providing that they were otherwise healthy and motivated when they took the test.[3] This diagnosis was applied to approximately 7 % of the students who were tested (Fancher 1985).

The creation of the Binet-Simon Scale marked the development of a completely revolutionary approach to the measurement of human intellectual functioning. Rather than relying on simple measures of reaction time and sensory acuity, Binet and Simon's test purported to measure higher-order processes such as memory, language, and attention. In particular, however, the researchers believed that their scale measured the subjects' capacity to exercise judgment. Although conventional academic wisdom purports that Binet and Simon did not have a clear definition of intelligence guiding their work, they were rather clear about their conceptualization of the construct:

> [I]n intelligence there is a fundamental faculty, the alteration or the lack of which, is of the utmost importance for practical life. This faculty is judgment, otherwise called good sense, practical sense, initiative, the faculty of adapting one's self to circumstances. A person may be a moron or an imbecile if he is lacking in judgment; but with good judgment he can never be either. Indeed the rest of the intellectual faculties seem of little importance in comparison with judgment. (Binet and Simon 1916/1973, pp. 42–43)

[3] Binet and Simon were keenly aware that physical problems could mimic psychological ones. Their experience at the laboratory school they set up revealed that 5 % of students experienced academic problems merely because they could not see the blackboard (Binet 1907).

Mental Orthopedics

In 1905, Binet submitted a report in which he outlined his recommendations for special education pedagogy. He was optimistic about opportunities to help subnormal children improve their intelligence, and he strongly disavowed the popular notion that intelligence should be viewed as a fixed and immutable quality. He later stated the case this way:

> I have often realized, with great sorrow, the existence of frequent prejudice against the educability of intelligence. The well-known proverb that says: "When one is stupid, it is for long" seems to be taken literally by some teachers … they don't care about less-intelligent pupils, they don't nourish any liking or respect towards them … Intelligence is not a unique, indivisible function, a particular essence, but it's made up of the cooperation among all the minimal functions of discrimination, observation, retention, etc., whose plasticity and extensibility have been verified … As a consequence, intelligence is susceptible t development; through exercise, training, and, above all, method, one will be able to increase one's attention, memory, judgment, and to become literally more intelligent than before. (Binet 1909/1973, pp. 100–102)

Binet developed a series of cognitive exercises he called "mental orthopedics," which he believed could raise children's intelligence. A particular focus of these exercises was improving the subjects' capacity to pay attention, since this seemed to be fundamentally lacking in many children of low intelligence. For instance, he advocated for the use of fun games like "statue" in which children had to freeze until they were permitted to move (Binet 1909/1973; see also Fancher 1985). In 1907, he set up three experimental special education classes where mental orthopedics could be practiced. (The law mandating special education would not go into effect for 2 more years.) It is notable, however, that he also advocated for educating intellectually normal and subnormal children together. He believed that this practice would provide positive models for the slower-learning children and healthy opportunities for the faster-learning children to exercise virtues of duty and solidarity (Binet 1909/1973 Binet and Simon 1908; see also Foschi and Cicciola 2006).

The Binet-Simon Scale Comes to the United States

The ultimate popularity of the Binet-Simon Scale owes a large debt to the actions of the American psychologist Henry Herbert Goddard (1866–1957). One year after Binet and Simon published the first version of their intelligence test, Goddard accepted a position as Director of Research at the Training at a school for feeble-minded children in Vineland, New Jersey. The United States did not possess a uniform system for defining, diagnosing, and classifying intellectual disability, and most educators and physicians depended on a highly subjective and unreliable "we know it when we see it" approach. Goddard was fairly confident in his own judgment in these matters, and he was convinced that most people who worked closely with disabled persons could also be relied on to make "rather accurate" intuitive judgments (Goddard 1908b, p. 12). However, as a scientist, he would have preferred an objective method, had one been available. But the major steps recently taken in France had not yet made their way across the Atlantic (Zenderland 1998).

For the next 2 years, Goddard experimented with several unsuccessful approaches to mental testing. In 1908, he took an extended trip to Europe to seek counsel with experts there. On one of these visits, he met a Belgian physician and special educator named Ovide Decroly, who shared a copy of the Binet-Simon Scale. Intrigued, Goddard brought the test back to the United States and tried the tasks with the students at the Vineland school. He discovered that the mental levels of the children generally corresponded to the intuitive judgments made by himself and the other members of the Vineland staff, thus providing evidence of criterion validity (Goddard 1908a). Soon thereafter, the American Association for the Study of the Feeble-Minded tentatively adopted Goddard's classification system as "the most reliable method at present in use for determining the mental status of feeble-minded children" (Rogers 1910). With this adoption, Binet's approach to intelligence testing became firmly entrenched in American society (Zenderland 1998). Over the next few years, Goddard distributed 22,000 copies of his English translation of the Binet-Simon test (Fancher 1985). It is an irony of history that the Binet test did not become popular in France until the mid-1900s, when a French social worker who had spent time in the United States brought a US version of the test back to France (Kaufman 2009; Siegler 1992).

The Binet Tests and US Immigration Restriction

Between 1890 and 1910, approximately 12 million immigrants attempted to enter the United States through the Ellis Island Checkpoint. Immigration critics warned that this generation was "less educated, more impoverished, and more culturally 'alien' than earlier groups of immigrants" (Zenderland 1998, p. 263). To allay fears, Congress passed an 1882 law prohibiting "idiots" and "lunatics" from passing through the gates. The law expanded in 1907 to include "imbeciles," feebleminded persons, and persons with physical defects that might prevent them from sustaining themselves through respectable employment (Zenderland 1998).

Goddard and his team were invited to Ellis Island to help enforce these regulations; the Binet-Simon Scale proved central to his task. The procedure Goddard developed in 1912 was a two-step process: one assistant would visually screen for suspected mental defectives as the immigrants passed by (using the intuitive judgment purportedly developed through close contact over many years). Those who appeared suspect would then proceed to another location where the other assistant would test them with a variety of performance measures and a revised version of the Binet Scale. The number of immigrants who were deported increased exponentially as a result of these screening measures (Zenderland 1998).

Binet's Influence on Future Intelligence Tests

Binet contracted an illness and died in 1911 at the age of 54. His premature death cut short a prodigious career in its prime. Even so, the legacy he left is staggering in its influence. Aside from the unparalleled accomplishment of the 1905 test and its subsequent revisions, Siegler (1992) notes the importance of Binet's willingness to discuss frankly the virtues and limitations of his scale, and his progressive ideas about the malleable nature of intelligence. These remain hot topics in the present day. His careful attention to empirical evidence—learned the hard way through embarrassing experiences in Charcot's laboratory—distinguished him from contemporaries, like Goddard, who were more comfortable trusting subjective expert judgment. The Binet-Simon Scale has been translated into dozens of languages and revised and adapted countless times by intellectual heirs who appreciated the originality and utility of the tasks. Even though more recent approaches to intelligence theory and testing vary considerably in their theoretical orientations and in their approaches to testing, many of the items on Binet's original scale have stood the test of time (see, e.g., the enduring popularity of the Stanford-Binet assessments) and would seem familiar to twenty-first-century test takers and psychometricians.

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12 From Psychometric Testing to Clinical Assessment: Personalities, Ideas, and Events That Shaped David Wechsler's Views of Intelligence and Its Assessment

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To many students of psychology, the name David Wechsler is synonymous with cognitive testing. Although Dr. Wechsler died over 30 years ago, new editions and revisions of the tests derived from his original Wechsler-Bellevue Intelligence Scale (W-B; Wechsler 1939) continue to list him as the sole author (e.g., Wechsler 2008, 2012, 2014) and new, but related, tests list him as senior author (e.g., Wechsler et al. 2004; Wechsler and Naglieri 2006). Wechsler's contributions to the field of psychometrics and intelligence testing go well beyond the assessment tool he first designed over 70 years ago. His test products are not only among the most widely used and most widely studied measures of cognitive ability (Wahlstrom et al. 2012), but they have also been translated into over a dozen languages and standardized on many different societies and cultural groups (Georgas et al. 2003). Despite the fact that many different reliable and valid cognitive assessment tools are available for sale, and even though significant advances have been achieved in the field of neuropsychology, the Wechsler products continue to retain their popularity (Kaufman 2009; Boake 2002).

Why do psychologists continue to prefer Wechsler scales over other tests? Certainly, the tests have excellent and evolving psychometric qualities, a wealth of research and commentary, and a valuable history of interpretation. Ironically, though, one reason for the resistance to changing from such heavy reliance on the Wechsler scales is likely because of the changes Wechsler initiated in the way contemporary psychologists think about and use tests. He was a strong advocate of elevating the tests from a purely psychometric approach to a more clinical approach (Kaufman 2009). To understand how Wechsler achieved this change, it is necessary to understand Wechsler from a historical perspective. Like other great psychologists, Wechsler was influenced by researchers who preceded him and by the dominant schools of thought that typified and influenced the culture of his time. As is often the case in science, serendipitous events also played a role in shaping Wechsler's views of psychological assessment. Wechsler has, in turn, had a profound impact on the manner in which modern

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psychologists assess intelligence. Many of his views on intelligence were forward thinking and continue to be relevant today.

People Who Influenced Wechsler

In the United States, at the turn of the twentieth century, the field of psychology began to change from a science that studied consciousness to a more practical science that mirrored the ambitions and attitudes of a pragmatic American society. Much attention was focused upon the new functionalist school of psychology that shifted the considerations of psychologists away from structuralism – the study of the structure of the mind, or what the mind is – to functionalism – the study of the functions of the mind, or what the mind does (Schultz and Schultz 2012). The functionalist school was directly related to the birth of applied psychology (which itself would give rise to clinical psychology), which took psychology out of the laboratory and placed it squarely into the real world. To examine the functions of the mind, psychologists focused on the study of memory, perception, feeling, imagination, and judgment. In order to successfully study these mental activities, psychologists of the time needed to develop and then use objective assessment methods.

One major influence on Wechsler's professional as well as personal life was James McKeen Cattell. Cattell was the first professor of psychology in the United States and, through his work, helped establish psychology, once regarded as a minor field of study, or in some cases a pseudoscience, as a legitimate science.

Cattell was interested in studying human abilities and combined his early laboratory training in Germany with his interest in statistical analysis, to gather large amounts of data he could tabulate and subject to statistical scrutiny (Cattell 1890). At the turn of the nineteenth century, Cattell published the results of his study conducted with Livingston Farrand in which they assessed 100 students enrolled at Columbia University on an array of measures that included tasks of sensorimotor effects, reaction times, and pressure thresholds (Cattell and Farrand 1896). Although at the time Cattell used the term *mental tests* to describe his measurements, these tests were, for the most part, quite different from tests that would later become the core of modern-day cognitive assessment. However, at least two of the tests, a test of memory, where the students had to remember and repeat strings of digits, and a timed "test of automaticity" that required the students to name colors, are very similar to tasks found on modern cognitive tests. Along with developing the tests themselves, Cattell and Farrand also gathered data on each of the students' cultural and socioeconomic backgrounds, as well as aspects related to their physical health. Cattell's early work on test development and standardization gave rise to the field of intelligence testing and must have made quite an impact on Wechsler who studied under Cattell at Columbia University.

In 1917, Cattell was fired from Columbia University for opposing the United States' conscription policy during World War I. Years later, Cattell successfully sued Columbia University, and in 1921, he used the money from that settlement to start The Psychological Corporation, a company dedicated to finding solutions to industrial problems via the science of applied psychology (Pillsbury 1947). One can only speculate on the influence that Cattell's difficult decision with regard to involvement in World War I might have had on Wechsler's own decision to apply for conscientious objector status when his time came to serve in the Army. Later, after graduating from Columbia, Wechsler would turn to Cattell to seek employment at The Psychological Corporation, the same company that would eventually publish Wechsler's intelligence scales.

Another major influence on Wechsler's professional life was Robert Sessions Woodworth, a student of Cattell's and a scholar of psychology who also taught at Columbia University. Like Cattell, Woodworth researched mental tests and in 1911, together with Frederic Lyman Wells, developed a version of the Substitution Test (Woodworth and Wells 1911), a form of which is familiar to the present-day psychologist as the

Digit Symbol, now Coding, subtest on the Wechsler scales (Wechsler 1944). In 1916–1917, Woodworth delivered a series of lectures which were later published under the title *Dynamic Psychology* (Woodworth 1918). Woodworth explained that his system of dynamic psychology was concerned with the cause and effect relationships of human behavior. He wanted to understand how humans learn and "what leads them to think and act as they do" (Woodworth 1918, p. 34). In the summer of 1917, Woodworth served as chief psychological examiner at the naval base in Brooklyn, NY, where his unit was responsible for administering group and individual tests to over 1,000 men as part of a trial that would eventually lead to the wide-scale testing of soldier recruits during World War I (Yerkes 1921). Of all the people who shaped Wechsler's persona and destiny, Woodworth is perhaps the most important for three reasons. First, Woodworth was Wechsler's mentor at Columbia University, and Wechsler completed both his master's degree and his doctorate under Woodworth's tutelage. Second, it is likely that Woodworth helped secure Wechsler a position in the Army as a psychological examiner during World War I (Wasserman 2012). Third, it is likely that Woodworth steered Wechsler away from any aspirations of employment in academia.

Cattell's desire to design a meaningful and purposeful test was achieved a little more than a decade later by Alfred Binet. In 1904, in the Republic of France, the Minister of Public Instruction sought to find a means by which children who were intellectually impaired could be excluded from public education and moved to special classrooms (Binet and Simon 1916b, p. 9). In order to assist in this endeavor, Binet and his colleague Théodore Simon developed and published in 1905 and revised in 1908 a set of tasks, arranged in order of difficulty, that were administered individually to children. The test produced a score called the "mental age" (MA) that was compared to the child's actual chronological age (CA). If the derived mental age was the same as the child's chronological age, the child was considered to be average. If MA was higher than CA, the child was considered to be advanced. If the MA was lower than the child's CA, the child was considered to be behind or "retarded." Many of the items on the original and revised Binet-Simon test are familiar to psychologists today. These include tasks such as unfinished pictures, where the child has to find the important part that had been omitted in a picture, and repetition of figures, in which the child repeats a series of dictated digits, the length of which varies according to the age of the child. The Binet-Simon Intelligence Scales also included a test which required the child to define words, and another that required the child to make change from 20 sous, a type of arithmetical reasoning. Each of these tasks is similar in nature to what Wechsler later included in his scale as the Picture Completion, Digit Span, Vocabulary, and Arithmetic subtest (Boake 2002). Binet and Simon's concept of intelligence was how well a person could adapt to a particular circumstance (Binet and Simon 1916a). This idea is reflected in the types of tasks they chose for their test.

The Binet-Simon test was brought to the United States in 1908 by Henry Goddard (1916), who arranged for the test to be translated into English. An American revision of the Binet-Simon scale was developed in 1915 by Robert M. Yerkes et al., and was called the Yerkes-Bridges Point Scale. Instead of grouping the tests by age level as in the Binet-Simon, the test items were consolidated into subtests and arranged in order of difficulty, with the examinee able to earn points for each correct response. The point scale model was later adopted by Wechsler for use in his tests (Kaufman 2009). In his role as Chief of the Section of Psychology in the United States Army during World War I, Yerkes, had an indirect impact upon Wechsler's future career as a developer of psychological tests.

In 1916 Lewis Terman, a professor at Stanford University and a pioneer in educational psychology, published the *Stanford Revision of the Binet-Simon Scale*, now universally known as the "Stanford-Binet" test. He adopted William Stern's (1912) suggestion that mental age divided by chronological age be used for an intelligence quotient or IQ. The Stanford-Binet was an extremely popular test for many decades (Louttit and Browne 1947) and in its current edition is still in use today. Terman believed that a good intelligence test could accurately assess abstract thinking, and therefore he emphasized the use of verbal and language-based tests of arithmetical reasoning and abstract thinking (Terman 1921).

Two other personalities that helped shape Wechsler's view on intelligence were Charles Spearman and Louis Thurstone. Spearman is credited with having constructed the first theory of intelligence (Kaufman 2009). Spearman (1904) theorized that individual intelligence could be represented by a unitary factor that he called *g*. He was able to demonstrate that different measures of mental abilities were all positively correlated, which indicated that there was an underlying global factor that represented intelligence. Spearman also theorized that certain mental tests would be better at measuring *g* than others. Wechsler referred to Spearman's discovery of *g* as "one of the great discoveries of psychology" (Wechsler 1944, p. 6). Wechsler's viewpoint as to the importance of *g* did not change over time. Kaufman (2009, p. 45) writes that when Wechsler visited him in 1975, he told Kaufman's students that "nothing is more important than *g* for understanding intelligence. Global ability is *the* ability that underlies my IQ tests."

In contrast to Spearman's unitary intelligence factor theory, Thurstone, a pioneer in the fields of psychometrics, believed that intelligence comprised seven independent groups factors (Guilford 1972). Thurstone's work in factor analysis led him to formulate a model of intelligence centered around "Primary Mental Abilities" (PMAs) (e.g., Thurstone 1938). These included verbal comprehension, word fluency, number facility, spatial visualization, associative memory, perceptual speed, and reasoning. Thurstone's model influenced hierarchical models of intelligence and would later influence the way Wechsler defined intelligence (Matarazzo 1972)

Wechsler's Early Life

Wechsler's early life did not presage his career, and he would have seemed an unlikely candidate for fame. The youngest of seven children of Jewish parents, he was born in the Kingdom of Romania in 1896, during a time of severe economic depression, which led to the enactment of anti-Semitic laws and the persecution of Jews (Matikainen 2006). At the time, Jewish residents of Romania were not eligible for Romanian citizenship and were thus excluded from many vocational occupations which were open only to citizens (Iordachi 2002). Even Jewish children were not immune from discrimination. As noncitizens they were barred from attending public schools unless their parents paid prohibitively expensive tuition fees. These conditions led to a mass exodus of Romanian Jews, who left the land of their birth for more tolerant countries. Between 1900 and 1902, Wechsler's parents and siblings made their way to the United States and found refuge in New York City. Before Wechsler's 11th birthday, both of his parents had died, and he was raised by his brother, Israel Spaner Wechsler, who would himself later become a renowned neurosurgeon. Wechsler attended City College of New York, earning an A.B. in 1916, and did his graduate work at Columbia University, earning a master's degree in 1917 and a Ph.D. in 1925. His first published article (his master's thesis) was a study of memory in patients with Korsakoff's syndrome (Wechsler 1917a). In his article, Wechsler lists the tests he used to evaluate the participants in his study. What is noteworthy is that Wechsler used a test he refers to as "auditory memory span for digits" and the Knox Cube Test (a nonverbal memory test which employs sequential taps on four blocks), which he refers to as a "visual memory span for movement" (Wechsler 1917a, p. 416). Versions of the auditory Digit Span are still found on the Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V; Wechsler 2014) and the Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV; Wechsler 2008). A cube-tapping visual memory test (long absent from Wechsler scales) is included in the WISC-IV integrated (Wechsler et al. 2004) and in the Wechsler Nonverbal Scale of Ability (WNV; Wechsler and Naglieri 2006). It is also interesting to note that in the Korsakoff syndrome study, Wechsler performed a "qualitative" (Wechsler 1917a, p. 417) as well as a quantitative "analysis of errors" (Wechsler 1917a, p. 423). This utilization and integration of separate measures of verbal and nonverbal abilities, coupled with an interpretive approach that combined both qualitative and quantitative analyses, would feature prominently in Wechsler's assessment tools several decades later.

World War I and Psychological Testing in the Army

In 1917 at the beginning of World War I, a meeting of the Society of Experimental Psychologists was held at Harvard University. Yerkes, then president of the American Psychological Association, addressed the attendees. His goal was to see how American psychologists could unite and contribute to the war effort (Yerkes 1921). One of the identified needs of the Army was the assessment of new recruits in order to know which tasks they were capable of performing. Individual testing was not a practical solution for the Army as it required significant amounts of time as well as highly trained test administrators. A protocol for testing large groups of recruits needed to be developed. After receiving the necessary approvals from the Army, Yerkes assembled a team of experts to develop a battery of tests that could be administered to large groups of men. Most of the tests were adapted from existing assessments. The team evaluated tests using criteria such as speed of testing, speed of scoring, minimal amount of writing, and (perhaps surprisingly for the time) the test's indifference to the amount of schooling a recruit had previously received. Yerkes (1921) credited Arthur S. Otis for devising and adapting the majority of these tests. The tests were tried out several times, and group scores were correlated with individual scores. The correlation between group and individual tests was reported to be 0.5, which led Yerkes to decide that group examination was acceptable. From these trials, two group administered tests were developed: the Army Alpha, designed for English-speaking recruits, and the Army Beta, administered to recruits who were illiterate or had limited proficiency in the English language. If a soldier was unable to pass the group examination, he was administered an individual test such as the Stanford-Binet, the Yerkes-Bridges Point Scale, or a test that had been developed by Yerkes' team called the Army Performance Scale. This testing project, which would eventually result in the assessment of over 1.7 million soldiers, including over 83,500 individual assessments required a large number of men with knowledge of psychological testing to administer these tests (Yerkes 1921).

On June 5, 1917, the day before Wechsler's graduation with a master's degree from Columbia University, the US government required all men between the ages of 21 and 31 to register for the draft to fight in World War I. Wechsler, who had turned 21 in January of that year, was no exception. Wechsler's war-time service is not only noteworthy for how it influenced his later career, but it is also somewhat controversial. Wasserman (2012) suggested that Wechsler tried to evade the war-time draft and notes that "Given his efforts to avoid military service in 1917, it might be considered ironic that the skills he acquired and contacts he made during his military service would shape his career in assessment and test development" (p. 33). Specifically regarding Wechsler's draft status, Wasserman wrote:

> After the U.S. Congress declared war on Germany in April, 1917, Wechsler (1917b) completed his required registration for the draft, listing himself as a "Consciencious [*sic*] Objector" and as an alien who was a citizen of Romania, who was disabled by "Near Sightness" [*sic*] and "Physical Unfitness." To the item asking about his occupation he wrote "Am student in school of philosophy." Wechsler's draft registration thus used multiple methods to avoid being drafted—claiming status as a conscientious objector, claiming exemption from military service by reason of alien (noncitizen) status, and claiming physical deficiencies that would disqualify him for military service. . . . Wechsler's status

> as a noncitizen native of Romania, some 15 years after his arrival in the United States also put him at risk. As an alien, he could not be drafted, but he could be deported. (2012, pp. 31–32)

Wasserman based these statements on information derived from a copy of Wechsler's draft registration card (Wechsler 1917b). Careful examination of the draft card and of the selective service laws in effect at that time does not fully support Wasserman's assumptions. Although he was not a citizen of the United States, Wechsler was most certainly subject to the draft under the existing draft laws. The Selective Service Regulations of 1917 (U.S. Office of the Provost Marshal General 1918, p. 52) stated that "when an alien has declared his intention to become a citizen, regardless of how long ago, he is still liable to draft, even though he has not in the meantime applied for final papers." In 1917, the process for becoming a US citizen had two steps. First the alien would declare his intention to become a citizen. This process was known colloquially as filing "first papers" (DeSipio 1987). Several years later, the alien would file a petition for naturalization, so-called final papers. On this point, it is interesting to note that on the Wechsler-Bellevue Intelligence Scale Form II (Wechsler 1946), Question 8 of the Comprehension subtest is, "Why does the United States require that a person wait at least two years from the time he makes application until the time he receives his final citizen papers?" Listed as one of the highest score answers is, "Gives them a chance to prove their sincerity and desirability."

It is almost certain that Wechsler had already filed his declaration of intent before the war broke out. Item 4 on Wechsler's draft registration card asks: "Are you (1) a natural-born citizen, (2) a naturalized citizen, (3) an alien (4) or have you declared your intention (specify which)?" The answer that is written on the card is "1st paper." Further proof that he had declared his intention to become a citizen can be found in his petition for naturalization, filed one day after Wechsler entered the Army on May 12, 1918 (Wechsler 1918). On the form, it notes that Wechsler had previously filed a petition for naturalization with the "Supreme Court of Kings County, Brooklyn, NY" on March 6, 1918. Since this civilian petition or "final papers" could only be filed three years after filing first papers, it seems likely that Wechsler filed his declaration of intent sometime around 1915 and thus became subject to US draft regulations in 1917. Wasserman also made the assumption that Wechsler filled out his own registration card. This does not seem likely. The entire draft card appears to have been completed by the registrar. The draft card comprised two sides, a front and a back. The back part of the form is titled "Registrar's Report," filled out by the registrar; it included observations that the registrar made about the prospective recruit. It is here that the registrar, not Wechsler, noted that Wechsler had possible disqualifying disabilities such as nearsightedness and physical unfitness. It seems likely that these were intended to be the objective observations of the registrar, as the registrar had to certify that his own answers were true.

One of the answers on the card can be misread easily because of the handwriting, which may be why Wasserman assumed that Wechsler filled out his own form. For item 7 "What is your present trade, occupation or office?" Wasserman noted that Wechsler answered "am student in school of philosophy" (Wasserman 2012 p. 31). Upon careful examination, we believe that the answer actually reads "A.M. Student in school of Philosophy" where A.M. is likely an abbreviation of *artium magister*, or master of arts—the degree that Wechsler was completing at the time of the registration. Wechsler, in fact, was awarded the degree the very next day (June 6, 1917) at the Columbia University commencement ceremony. Furthermore, a careful examination of Wechsler's signature on the card shows that it does not match the cursive handwriting used to complete the rest of the document, and, additionally, the color of the ink used for the signature seems different from the rest of the form. It is possible that Wechsler was a bona fide conscientious objector, willing to serve his adopted country but requesting to do so in a noncombatant role. It is equally possible that Wechsler claimed to be a conscientious objector in order to escape the possibility of live combat. There is, however, no evidence that favors either of these possibilities nor is there any evidence that Wechsler tried to avoid (noncombatant) military duty.

Wechsler did enter the Army in 1918 and while waiting induction at Camp Yaphank in Long Island, NY received some preliminary training in the administration and scoring of the Army Alpha Test (Matarazzo 1972). In May of 1918, he attended basic training at Fort Greenleaf, Georgia, and in August was assigned to Fort Logan, Texas, where he was part of the psychology unit (Yerkes 1921). His responsibilities at Fort Logan consisted primarily of administering individual psychological tests, one part of the mass psychological examining of recruits that occurred during World War I. It is in the Army that Wechsler's main ideas about the nature of psychological evaluation were formulated (Boake 2002).

Postwar Experiences and Training

At the end of the war, while soldiers stationed in Europe waited to return home, some were able to participate in higher education courses such as law and medicine. This program was known as the American Expeditionary Forces (AEF) University (Cornbise 1997). Although it is unclear exactly how, Wechsler was able to take advantage of this program. He transfered to France and later to the United Kingdom, where he worked with notable contributors to the emerging science of human intelligence such as Charles Spearman and Karl Pearson, both of whom are renowned for their research into statistical analysis.

Wechsler obtained a 2-year fellowship to the Sorbonne in France and there studied the "psychophysiology of emotions" (Boake 2002). He returned to the United States in 1922 and completed his doctorate at Columbia University in 1925 with Woodworth as his mentor. Much of the research that Wechsler had done at the Sorbonne was used in his doctoral dissertation. One of the research issues Wechsler sought to explore was whether there was evidence for the existence of a general emotional factor, similar to the general intelligence factor identified earlier by Spearman. Wechsler, however, did not find any evidence to support this factor (Matarazzo 1972).

After graduating from Columbia, Wechsler was unable to find steady employment. We can speculate that some avenues of employment might not have been open to Wechsler because of his religion. In those years, careers in academia were not always open to Jews (Schultz and Schultz 2012). Even Wechsler's mentor, Robert S. Woodworth, was not immune to the prejudices of his times. In 1929, Woodworth made it clear to a Jewish student named Daniel Harris that Harris could not become his assistant on account of Harris's religion. Woodworth advised Harris to seek career opportunities outside of academia (Winston 1996).

It is interesting to speculate about how different the history of intelligence testing might have been had Wechsler been able to obtain a career in academia. Perhaps Wechsler might have settled into a long, distinguished professorship with many publications but nary a test to his name.

After short stints at various locations (including 5 years in private practice), Wechsler eventually found employment at The Psychological Corporation as an unsalaried employee. During his time there, he performed a study, funded by the newspaper the *New York World*, that measured the intelligence of women, using a sample of chorus girls (Edwards 1974). He also developed a test that measured the intelligence and alertness of taxi drivers for the Yellow Cab Company of Pittsburgh. The test employed mechanical instruments that Wechsler developed himself. Wechsler had already patented a machine he called the *photogalvanograph* that measured the "variations in the electrical conductivity of the human or animal skin every time the individual is subjected to an emotion" (Wechsler 1924). Wechsler criticized those who would use the photogalvanograph for determining a person's guilt of a crime (Jones and Wechsler 1928). At the time, some utilized the machine with a test that included reading a list of words to a suspect. The list was purposefully designed to include some words that were meant to trigger an emotional response. Jones and Wechsler were able to show that the test results lacked reliability if the procedures were not standardized properly, including the careful location of the trigger words in the list. Wechsler's forward-thinking approach to test validity and reliability would come to good use when he developed his own intelligence test.

The Development of the Wechsler-Bellevue Intelligence Scale

Wechsler was hired in 1932 by Bellevue Hospital in New York, where he eventually became the hospital's chief psychologist, remaining until he retired in 1967. In 1932, Wechsler wrote a short paper describing what he saw as the advantages of the Army Alpha test over the Stanford-Binet, namely, the examiner's ability to analyze the subtests of the Army Alpha test to determine individual "special abilities and disabilities". Here is the first time that analysis of strengths and weaknesses is mentioned. In 1935, Wechsler published a book he considered to be one of his best works, *The Range of Human Capacities*. In this book, Wechsler used Army Alpha data among other sources to argue that abilities peaked at a certain age and then began to decline. He also argued very strongly that psychologists had overestimated the range of variations among individuals and that human beings were actually surprisingly similar.

By the time Wechsler began developing his first intelligence test during the 1930s, he had identified several key problems with existing tests that he felt needed to be addressed. He believed that the existing tests were heavily loaded on verbal items that sometimes produced scores that did not reflect the real-life intelligent functioning of the examinee. Wechsler was aware of some of the problems that existed with earlier tests because of his first-hand experience testing soldiers during World War I. In 1935, Wechsler argued that the mental age or IQ assigned to an examinee often did not accurately describe the functionality of that in individual in real life. Wechsler understood that a person could score poorly on a test and yet function adequately in society. Wechsler related an early experience he had in the Army in which he evaluated a 28-year-old, white, Oklahoman soldier who had failed the Army Alpha and Beta tests. He administered both a Stanford-Binet and a Yerkes-Bridges Point Scale, and the man obtained a mental age of eight yet was able to function perfectly well as a soldier in the Army. Before joining the Army, the man worked as an oil driller, earning enough money to support his family. Wechsler also stated that the tests were completely inadequate in appropriately measuring the true mental abilities of foreign-born adults and African-Americans (1935a).

The Wechsler-Bellevue Intelligence Scale was published in 1939 and it contained several innovative features (Kaufman 2009). Wechsler used standard scores, which he referred to as deviation IQ scores, acknowledging that he borrowed this concept from other tests (Wechsler 1949a). He set the mean score, somewhat arbitrarily (Kaufman 2009) at 100 with a probable error of 10 or standard deviation of 15, which was (intentionally or not) fairly close to the middle of the range of standard deviations of the ratio IQs found on the revised Stanford-Binet (Terman and Merrill 1937; see McNemar 1942). The deviation IQ score offered several distinct advantages over the existing ratio IQ scores. As opposed to the ratio IQ score, the statistical meaning of a score on Wechsler's test did not vary from year to year. For example, a score of 115 would be in the 84th percentile at any age and a score of 85 would always be in the 16th percentile. If an examinee maintained roughly the same ability level on the test compared to peers, the examinee's score would not vary just as a function of age. The score was meaningful, regardless of age. Deviation IQ scores were also better suited to measure developing cognition in children as cognition does not increase uniformly as children age (e.g., the difference between the average cognition of a 1-year-old and 3-year-old is greater than the difference between a 15-year-old and an 18-year old). Another advantage of the deviation IQ was that mental ages and ratio IQs were especially meaningless for adults and required selecting an arbitrary maximum chronological age to use for older examinees and ways of designating mental ages above that level.

Wechsler also made use of the subtest point-scale method that had appeared on the Yerkes-Bridges Point Scale as opposed to the age scale that appeared on the Stanford-Binet. The Wechsler-Bellevue also corrected the overemphasis on verbal tests that appeared on tests the Stanford-Binet and similar tests. Wechsler weighted the verbal and nonverbal (performance) tests more or less equally (Kaufman 2009). Finally, Wechsler used census data to create an unbiased normative sample matching age, gender, and occupation to US census data (Wechsler 1944). Although his urban sample could not be matched exactly with rural occupations, Wechsler used Yerkes's (1921) report to find the IQs of people with specific urban occupations that were similar to the IQs of agricultural workers. This allowed Wechsler to substitute urban occupations for rural ones. For the time, these methods of standardization and norming, carried out personally by Wechsler and colleagues without the support of a publisher, were quite advanced (Kaufman 2009).

The Wechsler-Bellevue was divided into two scales, a Verbal scale and a Performance scale. The subtests on the Verbal scale were Information, Comprehension, Arithmetic, Similarities, and Digit Span, with Vocabulary serving as an alternate test. The subtests on the Performance scale were Digit Symbol, Picture Completion, Block Design, Picture Arrangement, and Object Assembly.

Almost all of the tasks that Wechsler chose for his original test were in fact adapted or adopted from other tests; primarily those Wechsler was intimately familiar with from his experiences as an examiner in the Army. Kaufman (2009) notes that "the similarity of Wechsler's original set of subtests to the tasks used to evaluate recruits, soldiers, and officers during World War I is striking." In fact, Wechsler (1944) stated this explicitly. He did not even change the names of many of the tests he borrowed. Wechsler's goal in developing the Wechsler-Bellevue was not to create new subtests or tasks but rather to select the best available measures of intelligence and combine them into a standardized, norm-referenced battery. Wechsler (1944) gives the source or sources for most of his tests. For example, the Information and Comprehension subtests were both adapted directly from the tests developed for use by the Army. Five of the ten items on the original Comprehension subtest were taken directly, some with only slight modifications, from the Comprehension test of the Army Individual Examination, while at least three other items were taken from the Army Alpha (Yerkes 1921). Items on the Arithmetic subtest were also adapted from the Army Individual Examination. Digit Span was derived from the Binet scales. Although Wechsler (1944) described in detail how he developed the word list for his optional vocabulary test, it too was derived from the Stanford-Binet test that was used in the Army.

Wechsler's Block Design was derived from a test constructed by Samuel Kohs called Kohs Block test (Kohs 1920). The Army Performance Scale had a somewhat similar test called Cube Construction. Wechsler (1944) notes that he changed the colors of the Kohs Block test, which had red, blue, yellow, and white blocks, to a simpler version using just two colors, red and white. This change might have been inspired by the Army's Cube Construction test in which the blocks had only two colors, red and natural wood (Yerkes 1921). Picture Arrangement also appeared on the individually administered

Army Performance Scale, although it had originally been developed for the Army Beta test. Wechsler adapted its pictures for his own test. Both Picture Completion and Digit Symbol were also borrowed from the Army Beta test. Digit Symbol (Coding) had been created by Otis and was based upon several versions of an older test called the substitution test, including the one designed by Woodworth (Yerkes 1921). Wechsler changed the administration time of Digit Symbol from 120 s to 90 s, although for the Wechsler Adult Intelligence Scale, Third Edition (WAIS-III), the allotted time was restored to two minutes (Wechsler 1997). Object Assembly was derived from the Army Performance Scale.

Wechsler believed that his tests were primarily to be used as clinical instruments, despite the fact that they could also provide important quantitative information. Part of Wechsler's success and the popularity of his instruments can be attributed to his ability to look forward and remain ahead of the curve by developing tests that met the demands of the professionals that used them. However, more important than the tests he developed is the way in which Wechsler transformed the "field of IQ interpretation from *psychometric measurement* to *clinical assessment*" (Kaufman 2009, p. 37). Wechsler's view of intelligence testing was that it was only one part of personality testing. He believed that an individual evaluation was not complete without an assessment of non-intellective factors such as temperament, morality, and social values (Edwards 1974; Wechsler 1943, 1950). He included items in his scales that would give the examinee an opportunity to express rational thinking, purposeful thought, and effective problem solving. For example, because he felt it was a clinically useful test for diagnosing low mental ability, Wechsler included Digit Span in the original Wechsler-Bellevue even though it was a poor measure of *overall* intelligence (Wechsler 1944). According to Kaufman and Kaufman (2001):

> Wechsler embraced the inclusion of items with clinical content in his test batteries, believing that they enhanced the more complete measurement of intelligent behavior and improved the value of the psychometric instrument as a clinical tool. Subsequent to Wechsler's death, the publisher of revisions of his batteries yielded to political correctness and removed virtually all of the clinically charged items, the very ones that Wechsler believed would assess aspects of EI [emotional intelligence]. (p. 260)

Theory of the Wechsler-Bellevue Test

Wechsler did not base his tests on any hierarchical theories of intelligence, although he clearly saw the subtests as measuring different aspects of overall general intelligence or *g*. The most recent editions of the Wechsler scales (Wechsler 2008, 2012, 2014) have all been updated to more accurately reflect current psychological and neuropsychological research as well as some aspects of a three-stratum, hierarchical theory of intelligence known as the Cattell-Horn-Carroll (CHC) theory (Flanagan et al. 2013). Confirmatory actor analysis supports the fit of the Wechsler Preschool and Primary Scale of Intelligence, Fourth Edition (WPPSI-IV; Wechsler 2012), WAIS- IV, and WISC-V into this model (Lichtenberger and Kaufman 2013; Raidford and Coalson 2014; Wechsler 2014). However the original theory behind the Wechsler-Bellevue and subsequent Wechsler scales is based on the author's definition of intelligence (Wechsler 1939):

> The aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment. It is global because it characterizes the individual's behavior as a whole; it is aggregate because it is composed of elements or abilities which, though not entirely independent, are qualitatively differentiable. (p. 3)

According to Wasserman and Kaufman (in press), Wechsler believed that this definition served to encompass the various theories that had influenced him. So when he speaks of "The aggregate or global capacity," he could certainly have been referring to Spearman's general intelligence factor. His emphasis on intelligence being "composed of elements or abilities" is similar to Thurstone's primary mental abilities. When Wechsler refers to the capacity "to think rationally," was he acknowledging Terman's emphasis on intelligence being related to the capacity for abstract thinking? Finally Wechsler's definition includes the concept of dealing effectively with one's environment, which pays tribute to Binet's notion of intelligence being the ability to adapt to different circumstances.

The Controversial Aspects of Intelligence Testing

Wechsler was a staunch defender of the utility and necessity of proper intelligence testing, something he referred to as an "intelligent test" (Wechsler 1966). In a letter to the *New York Times* (Wechsler 1949b), he noted that IQ tests were reliable and valid and were more "definitely diagnostic" than an electrocardiogram. However, intelligence testing was controversial in Wechsler's day and remains controversial today (Kaufman 2009). Part of the reason for this controversy can be attributed to some of Wechsler's contemporaries who advocated the use of intelligence tests in support of their opinions on race, eugenics, and immigration. For example, in the first chapter of the Stanford-Binet manual published in 1916, Terman was explicit about his goals for the Stanford-Binet test. It was his hope that the routine testing of "feebleminded" individuals would result in some type of government action to limit their ability to reproduce. For Terman, the primary use of the intelligence test was to identify "mental defectives." The link between crime, vice, "industrial inefficiency," and people with limited mental abilities was unequivocal.

Goddard advocated for the use of mental tests to identify the feebleminded among prospective immigrants to the United States. In 1912, Goddard visited Ellis Island and administered the Binet test to an immigrant that he perceived as being feebleminded. The immigrant spoke no English, and the test was administered with the help of an interpreter. The results of the test confirmed Goddard's suspicions: the immigrant was mentally deficient. Goddard remained unswayed even when the interpreter told him that upon his own arrival to the United States, he himself would have been unable to answer many of the items on the test (Schultz and Schultz 2012).

The Army test data that had been gathered during the war were made available to psychologist Carl Brigham, an assistant professor at Princeton University. In 1923, he published *A Study of American Intelligence*, summarizing the data of the various Army tests. The foreword to the book, written by Yerkes, warned that the United States could not "afford to ignore the menace of race deterioration or the evident relations of immigration to national progress and welfare" (Brigham 1923). The data showed that the admittance of "intellectually inferior" immigrants, defined as those immigrants from non-Nordic countries, contributed to the decline of American intelligence. According to Brigham, the solution was to heavily restrict immigration to the United States, and in 1924 the US Congress did enact legislation that sharply curtailed levels of immigration (Kamin 1974).

It is worthwhile to correct a misperception that has recently appeared in the literature regarding the lower scores of non-native English speakers on the Army Beta. Ortiz et al. (2012) wrote:

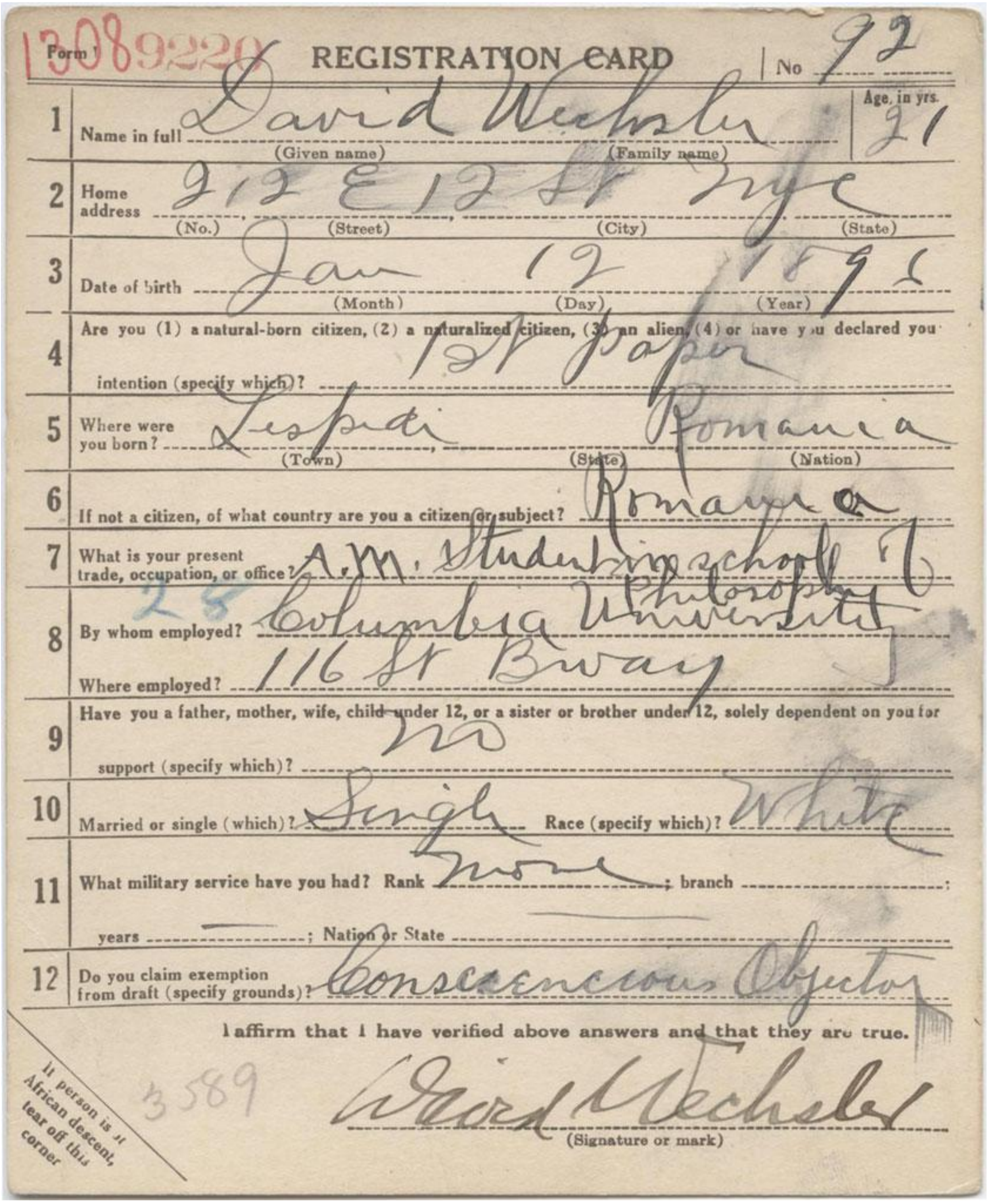
> In examining his data on nearly 1.75 million American men, Yerkes noted that the average raw score on the Beta for native English speakers was a stout 101.6, which classified them as Very Superior (Grade A). In contrast, the average raw score for non-native English speakers (who could also not read English) came in at only 77.8, which classified these individuals as Average (Grade C). For Yerkes, as well as the contingent of other notable psychologists working with him (e.g., Carl Brigham, David Wechsler, Lewis Terman), the results confirmed their own beliefs—that immigrants, particularly those from certain countries and from lower classes, were merely displaying their inherited lack of intelligence. (pp. 537–538)

Ortiz et al. are correct in noting the manner in which some of psychologists misinterpreted the Army data as a result of their prejudiced views regarding immigrants. There is no evidence to suggest that Wechsler had the same beliefs regarding the intelligence of immigrants as did Yerkes, Brigham, and Terman. He was a junior member of psychology staff in the Army and had yet to become a notable psychologist. In fact, as an Eastern European immigrant, persecuted because of his religion, Wechsler would likely have disagreed with the beliefs of his older contemporaries. Wechsler developed his test in part as an attempt to correct some of the flaws that existed with earlier tests, such as the emphasis on verbal tests. He defended intelligence tests against accusations of cultural and racial bias. As mentioned previously, Wechsler believed that on the whole people are not very different from each other (Wechsler, 1935b). Furthermore, Wechsler was careful to note that he had not included a sample of African-Americans when he developed the Wechsler-Bellevue and cautioned against using the test with that population. (Wechsler 1944).

In 2011, Fox et al. published the results of a study from the Bucharest Early Intervention Project (BEIP). The goal of this project was to introduce early intervention services and foster care into Romania and to study the results over a period of a decade. The authors examined the IQ scores of 103 participant in the BEIP, eight years after they entered the program. All of the children participating in the study had come from deprived home settings. The researchers found that the children who had participated in the early intervention program had significantly higher scores than a control group of deprived children who had not participated in the program. In their methods section, the authors report that the participants' IQs were measured using the WISC-IV (2003). It seems almost poetical that over a century after he was forced to leave Romania, his native land, one of Wechsler's tests was used as part of a program there to improve the quality of life of deprived children. In light of the results achieved by Fox et al. (2011), Wechsler's (1966) words in the *New York Times Magazine* ("The I.Q. is an Intelligent Test") provide yet another example of his forward-thinking approach to intelligence testing:

> It is true that the results of intelligence tests, and of others, too, are unfair to the disadvantaged, deprived . . . but it is not the I.Q. that had made them so. The culprits are poor housing, broken homes, a lack of basic opportunities, etc. etc. If the various pressure groups succeed in eliminating these problems, the I.Q.'s of the disadvantaged will take care of themselves.

Appendix


13089220

Form 1 REGISTRATION CARD No 92

1 Name in full David Wechsler (Given name) (Family name) Age, in yrs. 21

2 Home address 212 E 12 St Nyc (No.) (Street) (City) (State)

3 Date of birth Jan 12 1896 (Month) (Day) (Year)

4 Are you (1) a natural-born citizen, (2) a naturalized citizen, (3) an alien, (4) or have you declared your intention (specify which)? 1st paper

5 Where were you born? Despedi Romania (Town) (State) (Nation)

6 If not a citizen, of what country are you a citizen or subject? Romania

7 What is your present trade, occupation, or office? A.M. Student in school of Philosophy

8 By whom employed? Columbia University

Where employed? 116 St Bway

9 Have you a father, mother, wife, child under 12, or a sister or brother under 12, solely dependent on you for support (specify which)? No

10 Married or single (which)? Single Race (specify which)? White

11 What military service have you had? Rank None; branch; years; Nation or State

12 Do you claim exemption from draft (specify grounds)? Conscientious Objector

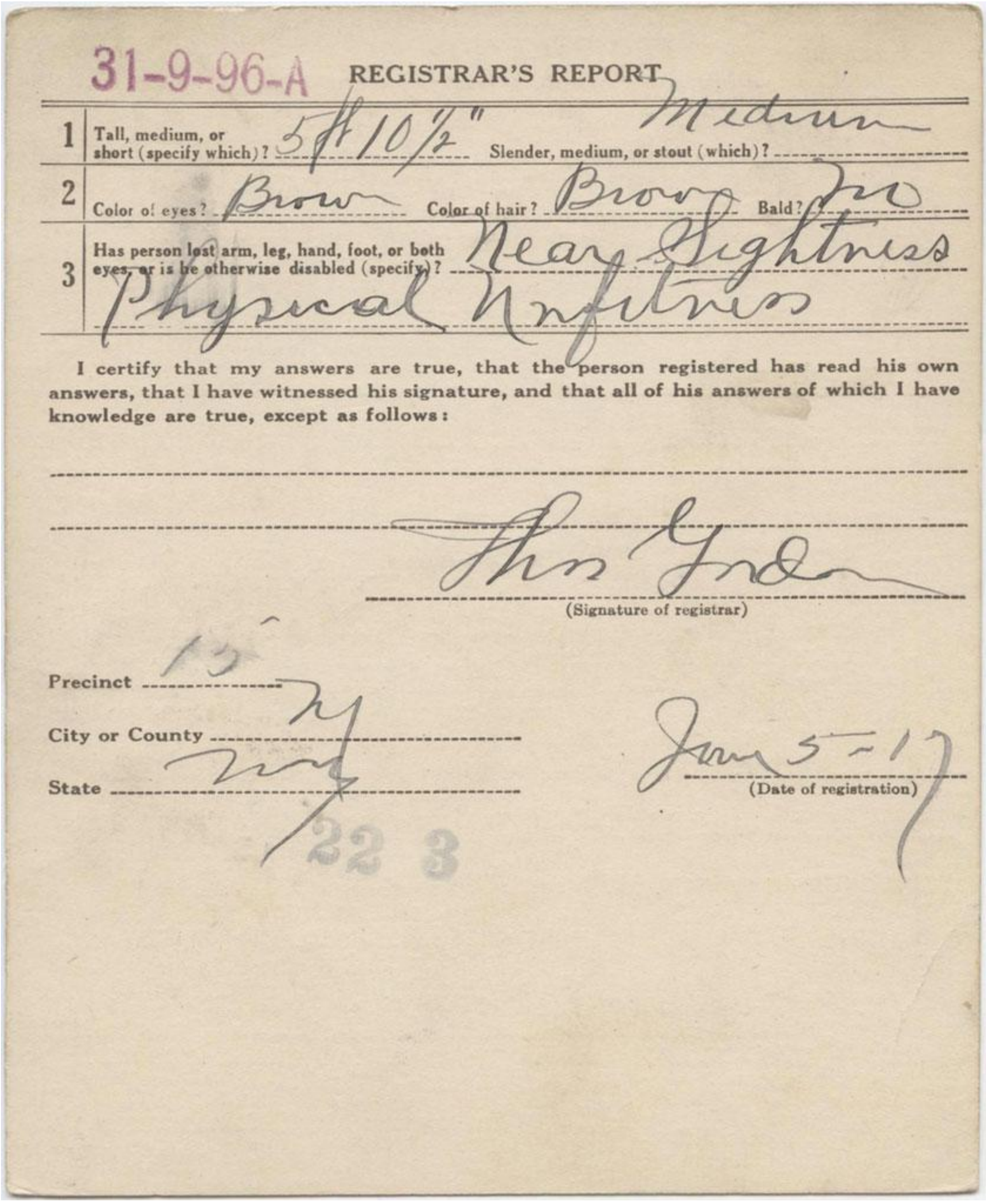
I affirm that I have verified above answers and that they are true.

3589

David Wechsler (Signature or mark)

If person is of African descent, tear off this corner

Fig. 12.1 The front and back of David Wechsler's World War 1 registration card. On June 5, 1917, all men ages 21–31 in the United States were required to register to determine eligibility for induction into the military. The response to question 4 "1st paper" indicates that Wechsler was eligible for the draft. It is likely that the A.M. in the response to question 7 stands for *artium magister*, or master of arts. From the National Archives and Records Administration. In the public domain



31-9-96-A REGISTRAR'S REPORT

1	Tall, medium, or short (specify which)? 5 ft 10½"	Slender, medium, or stout (which)? Medium
2	Color of eyes? Brown	Color of hair? Brown Bald? No
3	Has person lost arm, leg, hand, foot, or both eyes, or is he otherwise disabled (specify)? Near Sightness Physical Unfitness	

I certify that my answers are true, that the person registered has read his own answers, that I have witnessed his signature, and that all of his answers of which I have knowledge are true, except as follows:

Thos Gordon
(Signature of registrar)

Precinct 15
City or County NY
State NY

Jan 5 - 17
(Date of registration)

22 3

Fig. 12.1 (continued)

Fig. 12.2 View of Dr. David Wechsler seated at a table, conducting a test on a patient. The date of the photo is unknown. The machine might be a version of the photo-galvanograph that Wechsler patented in 1924 (Image courtesy of The Lillian and Clarence de la Chapelle Medical Archives at NYU)

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A.R. Luria and Intelligence Defined as a Neuropsychological Construct

13

Dana Princiotta and Sam Goldstein

Gedenkschrift to the Father of Neuropsychology

July 16, 2002, marked an important date in the world of neuropsychology. This centennial day celebrated the significant contributions of the Russian neuropsychologist Alexander Romanovich Luria, born in 1902. A world-renowned scientist, Luria's theories continue to excite experts more than 30 years after his death. By the 1980s, following Luria's death (August 14, 1977), a survey of neuropsychologists found that he was revered as "number 1" among the ten founders of neuropsychology (Akhutina and Pylaeve 2011). Underestimating this legacy in a single chapter is an unfortunate inevitability when asked to chronicle Luria's unequivocal impact on the practice of psychology and neuropsychology worldwide.

Procuring the title "father of neuropsychology" necessitated contributions in both the psychological and medical realms as neuropsychology was growing to be a recognized field of study. One of Luria's many acclaimed works, *The Working Brain* (1973a), was written by only 30 years into clinical neuropsychology's gestation (Cole et al. 2006). The immense magnitude of Luria's legacy is not fully appreciated by most scholars because of the political and linguistic deterrents surrounding Luria's work. Despite publishing extensively over the course of 50 years, a complete biography encompassing all published works does not exist (Cole et al. 2006). Rationales for this are associated with challenges in physically locating his publications and in translating works written in Russian. In Luria's 50-year contribution to neuropsychology, he authored more than a lifetime's worth of work. Nearly 40 years following his death, we continue to reflect on Luria's philosophies.

Born to Jewish parents in Kazan Russia, Luria's parents pursued careers in medicine and dentistry despite political tensions in Russia. Luria's father (Roman Albertovich Luria) was a physician at the University of Kazan; his mother was a dentist. Luria's sister followed the familial calling and pursued psychiatry. Luria's formal pursuit of higher education began at the age of 16 when he was accepted at Kazan State University. Against his father's wishes, Luria pursued psychology. During his studies at the University, he started the Kazan Psychoanalytic Association. He graduated in 1921 at the age of 19. Luria completed his studies while the Russian Revolution was underway. In 1924, Luria was introduced to

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Lev Semionovich Vygotsky, setting the stage for a lifetime collaboration and the inauguration of Luria's 50-year career.

The Vygotsky Circle

Much of Luria's earlier documented work arose under the guidance of Vygotsky. Luria, Vygotsky, and a team of scholars including medical specialists, neuroscientists, psychologists, and educational specialists collaborated to investigate the processes and psychology involved in an individual's maturation as it related to culture (Luria, Cole, & Cole, 1979; Cole 2005a). This collection of scholars would become known as the Vygotsky Circle (Luria, Cole, & Cole, 1979). Exploiting the terms *historical, cultural*, and *instrumental*, the circle aspired to "discover the way natural processes such as physical maturation and sensory mechanisms become intertwined with culturally determined processes to produce the psychological functions of adults" (Luria, Cole, & Cole, 1979, p. 43). Much of this work was facilitated in the early years by the Institute of Psychology in Moscow.

The term "cultural-historical psychology" was one of the prominent earliest contributions from the collective Vygotsky Circle. Ideas, theories, and research flourished under Luria, Vygotsky, and Alexey Leontiev's guidance (Cole 2005a). The Vygotsky Circle paid tribute to the interaction of nature/nurture and natural/cultural factors contributing to the development of the mind, with particular focus on the cultural, historical, and instrumental aspects of psychology (Kotik-Friedgut 2006). They aimed to "discover the way natural processes such as physical maturation and sensory mechanisms become intertwined with culturally determined processes to produce the psychological functions of adults" (Luria, Cole, & Cole, 1979, p. 43).

Within a cultural-historical framework, the underpinnings of Vygotsky's work supported Luria in speculating that cognitive processes in humans are organized in a way that thought and language are closely related, suggesting that spoken language reflects thoughts (Kaczmarek 1999). Luria expounded further and proposed that children are first introduced to linguistic commands by adults and then in turn adopt "self-commands" beginning as commands spoken aloud and then internally; thus, language mediates human behaviors (Kaczmarek 1999). "The development of any type of complex conscious activity is at first expanded in character and requires a number of essential aids for its performance; not until later does it gradually become condensed and converted into an automatic (motor) skill" (Luria 1973a; Kotik-Friedgut 2006, p. 48).

Luria examined the developmental differences as they relate to nature and nurture with his famous twin studies in the 1930s. He studied identical and fraternal twins at the Medico-Genetic Institute in Moscow. Luria believed that genetic contributions to behavior manifested expressly during tasks requiring natural cognitive processes rather than tasks relying on "culturally mediated processes" (Cole et al. 2006, p. 83). Working with five sets of identical twins, Luria utilized differing levels of instructions for twin dyads. The results suggested almost equal abilities in the tasks requested by the examiners; however, differences were apparent in their language and the ability to repeat the task from memory 18 months later (Bowden 1971). This implied that functions could be considered acquired, as the genetic factor was held constant in this study (Bowden 1971).

Subsequent studies focused on the development of speech in 5-year-olds with minimal speech development. A twin that was encouraged to verbalize his/her thoughts and desires developed speech much quicker than a twin confined to an "indifferent" adult, thereby highlighting the importance of the social component necessary to acquire language (Bowden 1971). This was best summarized by Kotik-Friedgut in 2006: "We always speak about things we see. We never speak about things we did not see. Prior to Luria's way of thought, the world was confined to concrete thinking; after Luria had his say, we were all more of the thinking that the ability to think abstractly was due to schooling and culture" (Kotik-Friedgut 2006, p. 44).

World War II and the Emergence of Neuropsychology

In the late 1930s, the Vygotsky Circle dispersed as German soldiers invaded the Soviet Union. The influence of the Vygotsky Circle resurfaced following the end of World War II. Due to mounting tensions in Soviet Russia in the 1930s, Luria embarked on a degree from medical school and focused much of his attention toward the aphasias. It is not surprising given Luria's intense interest in the acquisition of language and the social environment as demonstrated with the Vygotsky Circle that Luria would turn his attention toward the aphasias. Luria was fascinated with the aphasias, particularly in the classification of sounds, speech production and in writing associated with aphasias (Kolb and Whishaw 2009).

The aftermath of World War II yielded numerous case studies by Luria of individuals suffering from various forms of aphasia (Bowden 1971). For example, Luria discovered that those individuals suffering from oral apraxias could manipulate speech sounds with the utilization of observing their own movements of the lips and tongue in a mirror, thus utilizing an "environmental component of the reorganized functional system" (Bowden 1971, p. 413). Those who study Luria's work closely recognize his association with traumatic aphasia. Luria devoted a book on this topic, outlining case studies of hundreds of individuals suffering from localized brain injuries during World War II (Cole et al. 2006). "It was during the war and its aftermath that neuropsychology became a full-fledged science" (Cole et al. 2006, p. 140).

One such case was *The Man with a Shattered World*. A World War II veteran named Saletsky suffered from brain damage from a bullet entering the posterior left hemisphere intersections of the parietal, occipital, and temporal cortexes (Kolb and Whishaw 2009). Luria would come to follow Saletsky's trials and tribulations and progress for 26 years. Saletsky never returned to a premorbid level of functioning (Kolb and Whishaw 2009). Stated by Luria, "the damaged areas of the cerebral cortex could not be restored. Hence when he tried to think, his mind had to detour around these scorched areas and employ other faculties with which to learn and try to recover some lost skills" (Luria 1972, p. 158; Kolb and Whishaw 2009). This period became the breeding ground for Luria's systematic approach to the brain and mental functions forming the backbone of neuropsychology (Cole 2005a).

In 1959, Luria described a second case study focused on a war wound suffered by V., an officer of the Polish army. V. was wounded in the left occipital-parietal region during the war (Luria 1959). Although speech and vision improved and V. recovered in these areas after 6 months, V. complained of "attacks of giddiness and nausea as well as photophobia and epiphora" (Luria 1959, p. 439). V. demonstrated defects of visual perception and oculomotor ataxia, among other difficulties. World War II yielded a forum in which medical and psychological scholars would come to study the brain more intimately than before, especially as it relates to traumatic brain injuries. "To signify the combination of these two enterprises, the 'neurological' and 'psychological,' the term neuropsychology was coined" (Cole et al. 2006, pp. 157, 158).

Following the war, Luria's work was interrupted when he was asked to leave the Institute of Neurosurgery due to his Jewish background. Eventually, he was invited to return. He continued his study of neuropsychology in the 1950s at the Institute of Neurosurgery until his time of death (Cole 2005a). For the field of neuropsychology to advance, Luria stated that neuropsychologists needed to focus on a more thorough understanding of the "neurophysiological mechanisms" that were responsible for operating brain structures (Cole 2005a).

Topography, Localization, and Functioning of the Brain

In the early half of the nineteenth century, phrenology, a then popular philosophy developed by a German physician, claimed that certain brain areas had localized and specific functions (Kolb and Whishaw 2009). Under the guidance of phrenology, Franz Joseph Gall concluded that the size of the brain areas was a significant indicator as to human behaviors (Kolb and Whishaw 2009). Now considered pseudoscience, neurologists and physiologists in the latter part of the nineteenth century continued to develop their understanding of the brain.

Although neurologists and psychiatrists of the 1880s were able to develop functional maps of the cerebral cortex (Cole et al. 2006), our understanding was greatly enhanced half a century later in the 1930s with Luria's assistance. "The discovery that a complex form of mental activity can be regarded as the function of a local brain area aroused unprecedented enthusiasm in neurological science. Within a short time many other brain centers for intellectual functions were found…" (Cole et al. 2006, p. 210). Our current conceptualization of the topography of the brain as well as localization of function was made possible by Luria's significant contribution.

Luria elaborated, "To say that the human brain operates as a whole means to make simultaneously a correct and an erroneous statement. It is correct because the most complex forms of human actions require the participation of all brain systems; it is erroneous because we can hardly admit that the Human Brain—this highest point of Evolution—works as an undifferentiated whole and that the quality of its work depends exclusively on the active mass of its excited tissue" (Luria 1969b, p. 9). The complexity of this statement would fuel much of Luria's work in the 1930s and beyond.

Multiple concepts existed in the 1950s related to brain functioning—the most popular entailed matching a specific mental function with a specific cortical area or matching all brain functions to all behaviors (Cole et al. 2006). Luria preferred to focus on a complete functional system rather than an isolated function (Luria 1973a). A complete functional system allows for the conceptualization of multiple components working together. "This means that all these apparently so widely different functions incorporate a common factor, and it allows an approach to be made to the more intimate analysis of the structure of psychological processes" (Luria 1973b, p. 42).

One of the major research questions at that time was whether a complex functional system could be localized. Luria did not suggest that this complex system could be grouped and located in zones of the cortex either (Luria 1973a). Rather, he suggested that different areas of the brain must be involved in this system and not necessarily neighboring each other nor even located near one another (Luria 1973a). At this point in time, two major camps were developing revolving around Luria's work, those favoring a localized view of the brain and those favoring an integrated system.

The terms "function" and "localization" have come under great scrutiny as a result of Luria's advancements in the field of neuropsychology. While neurologists may argue one point about function and localization, a neuropsychologist may argue another. In the words of Luria himself: "Supporters of the first (narrow localization) approach started with the viewpoint that both elementary and higher (mental) functions must be viewed as an immediate function of narrowly limited parts of the brain; therefore they found it possible to speak of zones in which such phenomena as motor and sensory images of words, the function of writing or counting, are *localized*, and considered that the loss of these functions is an unequivocal symptom of damage in a corresponding zone of the brain cortex. Supporters of the second (anti-localization) approach, outwardly beginning from the opposite conception, in fact share the principal position of their opponents" (Luria 1964, p. 5).

In further illustrating his tenets of localization and functioning, Luria equated the meaning of the term function with that of bodily organs, including the function of the liver or pancreas, further arguing that the function of a particular brain area cannot be likened to the functioning of an organ (Luria 1973a). To think that most mental processes could be using "isolated or even indivisible faculties, which can be presumed to be the direct function of limited cell groups or to be localized in particular brain areas" cannot be true (Luria 1973b, p. 29). "Furthermore, these functional systems are not in 'narrow zones of the cortex' but must be located throughout the brain, regardless of location from another team member of the functional system" (Luria 1973b, p. 31).

Luria believed that one could not reduce this question to a simple concept in which a disturbance of a mental function is the direct result of the destruction of a specific part of the brain—thus providing confirmation that the function is localized in the damaged portion of the brain (Luria 1973b, p. 34). "It should be apparent that if the operation of intellectual processes is thought of in terms of functional systems instead of discrete abilities, we have to reorient our ideas about the possibility of localizing intellectual functions … our solution has been to think of the functional system as a working constellation of activities with a corresponding working constellation of zones of the brain that support the activities" (Cole et al. 2006, p. 141). This might be one of the biggest distinguishing features between the human and animal brain (Luria 1973b, p. 31). The meaning of localized brain damage as it relates to these higher mental functions began for Luria through the Vygotsky Circle (Cole et al. 2006).

Luria did not make the mistake of attempting to map out the precise locations with specific higher cognitions occurring when he explained his three functional units of the brain. To do so would suggest that parts of the brain were functioning independently. In other words, one could not select a cognitive task and assign the task as only relying on one type of processing or ability (Luria 1973a; S. Goldstein, personal communication, July 13, 2013). In Luria's words, "…perception of memorizing gnosis, and praxis, speech and thinking, writing, reading and arithmetic cannot be regarded as isolated or even indivisible faculties…" (Luria 1973b, p. 29).

Luria is perhaps most remembered for his teachings in the organization of functional brain systems including energizing, coding, and planning and the cultural contribution of the environment (Cole 2005a)—the key point aimed at the methodological conjunction of both theory and practice (Cole 2005a, p. 40). The essential tenets of the functional structure and brain organization, or higher mental functions, began with Vygotsky and continued with Luria (Akhutina and Pylaeve 2011). Rather than taking a "horizontal" viewpoint, Luria focused our attention to "vertical" perspectives of both the surface brain structures and deeper brain structures (Cole et al. 2006, p. 159). A discovery that the brain structures responsible for cortical tone are actually housed in the subcortex and brain stem (i.e., the structures influence tone and are regulated by the structures) radically altered the trajectory of neuropsychology (Luria 1973a).

Higher Mental Functions

Over the course of his impressive career, Luria was engaged in diverse case studies of individuals with extraordinary abilities and deficits alike. While we have briefly touched upon two of Luria's famous case studies demarcating deficits, the case of S. chronicles a case of greater faculties. In the *Mind of a Mnemonist* (1968), Luria described one of his most famous case examples, S., a man with fascinating abilities in the area of memory. S. first came to Luria after S.' employer noted that he never took notes during meetings (Kolb and Whishaw 2009). Remarkably, S. was able to visualize stimuli mentally and recall stimuli by reading from an internal "photocopy" of the original (Kolb and Whishaw 2009). Interestingly, S. also met diagnostic criteria for synesthesia, an ability to perceive a stimulus of one sense as the sensation of a different sense (e.g., tasting colors) (Kolb and Whishaw 2009). What allowed S. to create an internal photocopy of the original? How do we begin to understand higher mental functions like S.' extraordinary memory?

In 1966, Luria described stages of functions that were imperative for the development of intelligence and executive functions (S. Goldstein, personal communication, July 13, 2013; Vygotsky, Veer, & Valsiner 1994). Only a few years later, the systemic-dynamic approach of brain organization of "higher mental functions" was refined through the work of the Vygotsky Circle (Kotik-Friedgut 2006). Luria described interconnected levels that assisted in explaining the relationship between the brain and behavior and neurocognitive disorders. These levels included the structures of the brain, the functional organization (based on structure), syndromes and impairments arising in brain disorders, and clinical methods of assessment (Kaczmarek

1999; S. Goldstein, personal communication, July 13, 2013).

Recall the cultural-historical theory in which Vygotsky and Luria proposed that environmental interactions were particularly salient in the brain and behavior. Expanding on Vygotsky's work, Luria suspected that higher mental functions (e.g., abstraction, memory, and attention), a term that will be repeated frequently in this chapter, have an origin in social matters (e.g., language and thought processes) and are "complex and hierarchical in structure" (Luria 1973b, p. 31; Kotik-Friedgut 2006; Goldstein, personal communication, July 13, 2013). This statement supports a theory in which human conscious activity is developed with the utilization of external aids or tools (Kotik-Friedgut 2006). Furthermore, "At the same time, the process of internalization in the development of higher mental functions takes place under the influence of a specific cultural context, thus shaping and moderating the process of development and the functioning of these basic cognitive abilities" (Kotik-Friedgut 2006, p. 43). As demonstrated in the case study of S., the optimal outcome is efficiency in cortical functioning in the areas of attention, memory, intelligence, executive function, and language.

Luria's particularly salient points are included in his books, *Higher Cortical Functions in Man* (1980) and *The Working Brain* (1973b). Luria (1973b, p. 43) proposed that the brain is comprised of three functional units, each of which are "hierarchical in structure and consist of at least three cortical zones built one above the other." In other words, each "unit" is further divided into three cortical zones, arranged vertically. Coined primary, secondary, and tertiary cortexes, Luria described the cortical areas as working together. As sensory information travels from the first to second to third zones, information in the tertiary zone may then be processed in the amygdala or the paralimbic cortex for memory and emotional processing (Kolb and Whishaw 2009). In *The Working Brain*, Luria described a complex functional system in which these three contributing units worked in constellation to "create" higher mental activities (Luria 1973a).

Providing further indication for these three units and their associated neuropsychological abilities and location in the brain, Luria stated that the brain stem, diencephalon, and medial regions of the cortex constitute the first functional unit (attention-arousal system) (Luria 1973a). More specifically, Luria was describing the midbrain, medulla, thalamus, and hypothalamus. Working together, these organs maintain appropriate cortical tone (Luria 1973a). "Recent formulations of these regions suggest that some structures at the level of the diencephalon and medial regions have reciprocal connections to the cortex through a variety of subcortical circuitries, potentially influencing a wide range of behaviors" (Koxiol 2009).

The occipital, parietal, and temporal lobes are associated with the second unit in the medial temporal portions positioned posterior to the central sulcus (Semrud-Clikeman, & Fine 2008; Goldstein, personal communication, July 13, 2013). The predominant role of the second unit is to process and retain external information such as sensory reception and integration. Here the sensory modality does correspond to a particular part of the brain (e.g., auditory stimuli to the temporal lobe) (Luria 1980). The second unit was under the guidance of three guidelines proposed by Luria: first, the makeup of cortical zones does not indeed remain the same during development; second, the specificity of cortical zone functioning decreases with development; and, third, with development, an increase in lateralization occurs (Luria 1980).

The third functioning unit is responsible for the regulation and evaluation of behavior, including self-monitoring (Luria 1980). The third functional unit, or the prefrontal area of the frontal lobes, "synthesizes the information about the outside world … and is the means whereby the behavior of the organism is regulated in conformity with the effect produced by its actions" (Luria 1980, p. 263). This unit manipulates the most complex components of human behavior such as consciousness, personality, voluntary activity, conscious impulse control, and linguistic skills (Das 1980; S. Goldstein, personal communication, July 13, 2013). Here we would expect to find the unit responsible for planning and executive functioning, namely, (McCloskey, Perkins, & Van Divner 2009; S. Goldstein, personal communication, July 13, 2013). Of the three units, the first and the third are the most related to one another; however, the second and the third unit rely on the first condition for collaboration efforts (Luria 1973a).

In other words, a person is permitted or able through these processes along with already acquired knowledge to navigate their fluid environments (Luria 1973a; S. Goldstein, personal communication, July 13, 2013).

Luria premised his hierarchical model on three main points:

1. Information is processed serially, one step at a time, by the brain. Information thus travels from sensory receptors → thalamus → primary cortex → secondary cortex → tertiary cortex (Kolb and Whishaw 2009).
2. Serial processing is hierarchical, with increased complexity at each level.
3. "Our perceptions of the world are unified and coherent entities" (Kolb and Whishaw 2009, p. 267).

Stated by Luria, these three units represent (1) muscle tone/walking, (2) processing/storing external information, and (3) programming/regulating/verifying mental activity (Luria 1973a, p. 43). Luria argued that every form of "conscious" activity was an output of the combined efforts of these three functional units working in unison (Luria 1973a). Luria was very fascinated by studying the interactions and specific contributions of these three functional units (Luria 1973a).

Subsequently, Daniel Felleman and David Van Essen would further refine this hierarchical model to include hierarchically organized cortical areas but with more than "one area occupying specific position relative to other areas, but with more than one area allowed to occupy a given hierarchical level" (Kolb and Whishaw 2009, p. 267). They coined this model a "distributed hierarchical system" in which the number of areas expands as we go up the hierarchy (Kolb and Whishaw 2009).

Beyond functional units, Luria provided an explanation for subdivisions he called zones (Luria 1973a). These zones are known as the primary, secondary, and tertiary zones. The primary zone is primarily responsible for units utilizing neurons to receive impulses from sensory organs. Put differently, the primary zone in the motor strip of the frontal lobe focuses on motor output (Kolb and Whishaw 2009; S. Goldstein, personal communication, July 13, 2013). The second zone has neurons employed to enable incoming excitation to be moved along to the tertiary zones (Luria 1973a). This zone sequences motor activity and speech production, for example. This tertiary zone is then responsible for the organization and integration of excitation received by sensory structures and rearranging stimuli into a linear order (Luria 1973a). Damage to the frontal regions is particularly troublesome in altering the behaviors and executive functions of individuals, due to its influence and connections with other cortical and subcortical areas of the brain including the thalamic, hypothalamic, and limbic systems (Kolb and Whishaw 2009).

Luria would focus a large portion of his career to understand the contribution made by units and zones of the brain to understand which mental activities are encompassed under the umbrella of which brain systems (Luria 1973b, p. 103). This is highlighted by one of Luria's salient quotes: "Finally I discussed the chief sources of our knowledge of the cerebral basis of mental activity and I showed that of these three sources—the comparative anatomy of the brain, methods of stimulation and methods of destruction of its individual areas—with respect to the analysis of the functional organization of the human brain it is the last which is evidently the most important" (Luria 1973b, p. 103).

Disturbance of Higher Mental Functions

Thus far, we have focused much of our effort toward describing the "function" from Luria's perspective. It is appropriate to now turn to dysfunction from Luria's perspective. As Luria has stated, "In order to learn more about human cognitive functions we must study both their unfolding and disruption" (Kaczmarek 1999).

One cannot assume that studying brain lesions will provide comprehensive, generalizable answers. Inherently, brain lesions destroy various areas of the brain, "not just one narrowly localized group of nerve cells" (Luria 1973b, p. 104). "The initial hopes for using disturbance of higher mental functions for local diagnosis of brain damage began to appear unfounded, and the possibility of using psychological symptoms for local diagnosis became a controversial issue" (Luria 1964, p. 4). Expounded by Luria, the brain is now functioning under "pathologically changed conditions," meaning that some elements of the brain may be completely destroyed while others function as normal—making it very difficult to study the brain of those under "pathologically changed conditions" and apply this to the neurotypical population or even to other individuals with brain injuries (Luria 1973b, p. 104). Furthermore, "Nothing can be more mistaken than such an idea and such an attempt to localize the symptom of apraxia (and consequently the function of praxis) in a narrow area of the cortex" (Luria 1973b, p. 35). And, "As we have seen, a local brain lesion does not lead to the direct loss of a particular mental condition; this was the view held by the supporters of narrow localizations" (Luria 1973b, p. 103).

Luria believed that any sustained damage to a pinpointed cortical area in earlier childhood would result in "a relatively elementary basis of mental activity, and it unavoidably causes a secondary 'systemic' effect, or an underdevelopment of higher structures built on these elementary functions" (Luria 1973b; Kotik-Friedgut 2006, p. 48).

However, in adults, Luria argued, damage to "higher zones" produces just the opposite effect—elementary functions would deteriorate depending on the secondary or higher forms of activities (Luria 1973a; Kotik-Friedgut 2006, p. 48). However, he did not suggest that higher mental functions are "built up as a second story over elementary processes. Rather, higher mental functions are the product of the marriage of elementary functions into the new system under new guidance" (Luria 1973b, p. 43).

One distinction between humans and animals applies to the frontal lobes of the brain—the last features of the cerebral hemispheres to be completely formed. Primates possess larger frontal lobes than other animals, maturing between 4 and 7 years of age in humans (Luria 1973a, p. 187). The distinction between the frontal lobes of primates and non-primates lies within voluntary attention. After all, "Man lives in a constantly changing environment, and these changes, which are sometimes unexpected by the individual, require a certain level of increased alertness" (Luria 1973a, p. 55). A disruption to the frontal lobes may lead to "substantial disturbances in the flow of intellectual processes" (Luria and Tsvetkova 1964, p. 97). "These patients do not make a programme, there is no consequent realization of an original plan, and actions take on the character of change trials, which easily fall under the influence of immediate impressions or perseverations. If the results achieved do not match with the original intention, the mistakes made are not recognized and not corrected" (Luria and Tsvetkova 1964, p. 107).

Along with aforementioned case studies derived from the aftermath of World War II, Luria and colleagues investigated a patient with a verified arachnoidal endothelioma (meningioma) at the Burdenko Institute of Neuropsychology, patient Zav in 1962 (Luria et al. 1964). With complaints of forgetfulness, headaches, and nausea, Zav had difficulties following through with instructions during her neuropsychological evaluation. Once language was more complex, her speech behavior was replaced by perseveration that disrupted her when attempting to answer questions (Luria et al. 1964). Luria and colleagues provided a wealth of information regarding Zav's progression through extensive neuropsychological examination. "Such deviation from the assigned instructions and the substitution of a simple response was shown with simultaneous complete retention of the instruction in the patient's verbal system. As with the other tasks, the process of relating her actions to the instruction was hampered. Recognition of errors was almost impossible" (Luria et al. 1964, p. 267).

Overall, much of Zav's ability to carry out actions was dependent upon the complexity of the instructions (Luria et al. 1964). "At first glance one may suppose that they preserve all the basic functions of the Human Brain. But this is not the case. Attentive observation shows how deep are the disturbances in the regulation and control of the conscious behavior of these patients" (Luria 1969b, p. 12). Further, "The suggestion, which has been detailed elsewhere, is that frontal lobe resection limits the subject's ability to organize and reorganize his behavior when flexibility is demanded, and especially when external cues to support such organization are wanting …the patient with frontal lobe destruction is often unable to fulfill instructions, is unable to inhibit impulsive reactions or to hold back the tendency towards fixed repetition of movement" (Luria et al. 1964, p. 258).

Luria postulated, "This means that symptoms of disturbance of any higher cortical function may be used for local diagnosis of brain damage, but that such a diagnosis can be carried out only when there is qualitative analysis or evaluation of the symptom. Such evaluation of the symptom is the fundamental task of neuropsychology" (Luria 1964, p. 13).

A Synopsis of Luria in the Final Decade

Luria corresponded with colleagues throughout the world, questioning their conceptualization and understanding of the extra-cortical organization of brain functions (Kotik-Friedgut 2006). Six years before his death, Luria corresponded with Professor Douglas Bowden in the United States. This correspondence, dated February 20, 1971, from Souhanovo, Russia, was included in Dr. Bowden's *Meta-principles in Luria's Neuropsychology*. Excerpts of this correspondence appear below (adopted and transcribed as it appears in Dr. Bowden's work). These excerpts very well summarize Luria's thoughts in his final years:

1. There are higher cortical (or psychological) functions specific to human being and not existing in animals. These specifically human psychological processes (or functions) derive from social sources, i.e., tool-using social behavior of man.
2. The most specific feature of these higher processes is that they are tool- or means-using processes. Animals do not use means, their behavior is not mediated by means, tools, or signs, and it is all unmediated, natural behavior, whereas human behavior is always mediated (tool- or means-using) or indirect structure, social by origin and voluntary (or conscious) by the modes of work.
3. This indirect, means-using behavior is mediated via speech—the most important system of tools or signs in human history. Language (or speech) has not only its semantic function, function of categorization of impressions, but its pragmatic or regulatory (or controlling) functions as well. By using language, man overcomes the direct influences of environment, and his behavior becomes no more field linked but is goal or plan linked.
4. The indirect, tool (sign)-using behavior starts a new form of cortical work: human cortex is no more a complex of work of different zones, organized by influences of the centrencephalic system (or natural drives): it becomes a historically organized, plastic functional system where language plays a decisive organizing role. That is why higher cortical functions of man have to be evaluated as functional systems of cortical zones, linked by the leading role of language as a decisive means of behavior.
5. The disorganization of the brain functions following local brain lesions is in no way a partial deficit (destruction of a spherical local function) and no more a total lowering of the general brain activity. It results in a disorganization of functional brain systems, each time resulting from a defect of a *basic factor* (according the locus of the lesion)—bringing series of primary symptoms and resulting in a series of *secondary symptoms* or functional (systemic) results.
6. The basic goal of neuropsychology is neither a pure *description* nor a direct reduction to a physiological issue but careful *psychological qualification* of the symptom (i.e., singling out the underlying factor and then a description of systemic results of the destruction or elimination of this factor), that is, the real way to the neuropsychological diagnostics of brain injury.

A Post-Luria World

After laboring in the field of neuropsychology for much of his adult life, Luria passed away on August 14, 1977, at the age of 75 from cardiac arrest. Luria's research continued directly and indirectly through his pupil named Alfred Ardila among others (Cole et al. 2006). Continuing work under the tenets of cross-cultural neuropsychology, Ardila is one of many scholars perpetuating the work of Alexander Luria (Kotik-Friedgut 2006). A centennial celebration of Luria's birth was not necessary to broadcast his true impact on the world. His contributions to the field of neuropsychology are immeasurable. Our current conceptualization of extra-cortical organization of higher mental functions is one of Luria's most notable principles (Kotik-Friedgut 2006).

Because of Luria's influence, the field of neuropsychology has progressed rapidly in recent years. He shaped the process of learning how we think, learn, and solve problems. "In terms of assessment techniques, Luria's methods are qualitative and flexible; he seeks links in functional systems, his methods are clinical-theoretical and case oriented" (Cole 2005a, p. 35). By contrast, North American neuropsychologists rely on psychometric, actuarial, quantitative, group studies" (Cole 2005a, p. 35). Furthermore, "By the early 1980s, neuropsychology was no longer confined to a few elite laboratories, and the new field of clinical neuropsychology blossomed in the clinics and hospitals. Since that time, three factors have enhanced the rate of change in neuropsychological assessment: functional imaging, cognitive neuroscience, and managed healthcare" (Kolb and Whishaw 2009, p. 806).

One of the many assessment tools in the field of neuropsychology today founded on Luria's theories is the Cognitive Assessment System (Naglieri & Das, 1997). The CAS was developed by J.P. Das and Jack Naglieri. The CAS attempts to measure the functional units described by Luria. Employed with children aged 5–17, the CAS tracks children as they mature, measuring their executive functioning through the years (Das 1980; S. Goldstein, personal communication, July 13, 2013). The functional dimensions of brain structures as described by Luria are described in terms of planning, attention, and simultaneous and successive processes or abilities (Luria 1966, 1973b, 1980; Das and Naglieri 1997). More popularly known as the PASS theory, these processes are based on Luria's neurodevelopmental model of stages of higher maturation (S. Goldstein, personal communication, July 13, 2013). The CAS has recently been revised for a second edition.

We previously outlined the three functional units, which apply to PASS theory: attention uses the first unit (i.e., midbrain, medulla, thalamus, and hypothalamus), simultaneous and successive the second, and planning the third (Luria 1973b; Koxiol 2009; S. Goldstein, personal communication, July 13, 2013). Simultaneous processing refers to the integration of stimuli into interrelated groups or a whole (e.g., following multistep instructions) (Das 1994). Successive processing involves sequencing of stimuli in a serial order (e.g., decoding unfamiliar words and speech articulation) (Das 1994). In a sense, the roles of successive and simultaneous processing are reversed. Planning, associated with the first unit, is a process in which an individual evaluates solutions to problems. Attention, also associated with the first function, entails a process in which an individual focuses on particular stimuli (Das 1994).

Concluding Remarks

Alexander Luria was active in the field of neuropsychology up to his passing. His work would not be forgotten. His unfinished publications would later be published by colleagues as *Paradoxes of Memory* (Cole et al. 2006). "Depicted by four approaches, Luria outlined the derivation of human characteristics, human consciousness, psychology as a biological science, and psychology as a unique science" (Cole 2005a, p. 37). In perhaps his last published article before his death, Luria continued his craft in both identifying and distinguishing psychological approaches to better confirm the tenets of his own philosophies (Cole 2005a, p. 35). One of the most poignant statements made by Luria on this subject was, "As I have said already, any human mental activity is a complex functional system effected through a combination of concertedly working brain structures, each of which makes its own contribution to the functional system as a whole" (Luria 1973b, p. 38).

In the famous words of Luria before his death in 1977: "In this respect neuropsychology is merely the most complex and newest chapter of neurology, and without this chapter, modern clinical neurology will be unable to exist and develop. Neuropsychology now has a firm foothold in clinical neurology and neurosurgery. This fact is a source of great satisfaction to the author who, together with his colleagues, has spent a good deal of his life in an effort to make neuropsychology an important practical branch of neurology. It gives him confidence that his scientific life has not been spent in vain, and that new and important prospects lie ahead for neurology, and for those important divisions of neurology—the topical diagnosis of local brain lesions and the rehabilitation of these patients" (Luria 1973a, p. 344).

Those familiar with Luria's work would likely express immense gratitude for his contributions and assure him that his scientific life was surely not spent in vain. Close disciples of Luria's work cannot begin to measure the salience of Luria's work as it relates to the current times.

The modern tenets of neuropsychology are built upon Luria's teachings, much as a religion's philosophies are built upon a book of God, such as the Bible. As Luria discussed the ever-changing climate of an individual's environment, so too, the climate of neuropsychology will continue to evolve. Having said that, the basic tenets of neuropsychology as provided by Luria will prevail in secure establishment as *the* foundation of neuropsychology. As stated by Luria a few years prior to his death, "Thus we are still very far from the solution of our basic problem—the Neuropsychological Organization of Man's Conscious Action, and we can only look forward with envy and hope to the work of the next generations of Psychologists who will one day take our place and bring to a successful end the work we have only started" (Luria 1969a, p. 20).

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Intelligence: Defined as Neurocognitive Processing

14

Tulio M. Otero

Introduction

Intelligence does not exist. Although this is a strange statement, it is a fundamental truth that must be understood before understanding what intelligence is and how we define it in this chapter. Intelligence is not a tangible entity that can be measured in the same way physicists measure matter. Rather, intelligence is a hypothesized "phenomenon." Its ontology, etiology, and scale are inferred through indirect means. We assume that intelligence is found in the brain, yet we cannot locate it. It is not a discrete, embodied force radiating from the brain that can be measured directly with sophisticated apparatus. There is nothing physical to set a ruler next to and claim, "this is how much intelligence is here" (e.g., Thorndike 1997).

Human intelligence is a psychological construct defined by many influential philosophers, researchers, and theoreticians at different points in history. Thorndike (1997) described a construct as a defensible collection of separate, quantifiable qualities and attributes that, when taken together, form a measurable exemplification of a multifaceted, hypothesized abstraction. Considering the definitions of intelligence as a construct is of significant importance. Clinicians and researchers may define intelligence in dissimilar ways. As a result, their findings may produce conflicting results. Failure to consider the underlying definition of intelligence makes accurate interpretation of collected data a tenuous process. Pluker and Esping (2014) present definitions of intelligence by 12 prominent historical and 7 contemporary theorists. Of interest is that only one researcher and theoretician, JP Das, defined intelligence as the "sum of all cognitive processes" (p. 19).

Intelligence as used in this chapter refers to a subset of psychological processes that involve cognition. Neuropsychological and neuroanatomical studies have elucidated that neuropsychological assets and deficits in cognitive processes can facilitate or impair specific types of learning and performance. An examination of anatomy also illustrates how and why some neurocognitive processes are interrelated. Basic psychological processes are important for any individual to be able to interact effectively with the environment, to learn from formal instruction and from experience, and to adapt to new situations. Our brain takes in and processes new information in such a manner that typically the right frontal lobe systems are engaged until new information is learned, assimilated, and accommodated into our existing knowledge base or becomes routinized (Goldberg 2009). Once information or knowledge becomes readily familiar, greater activation of the left frontal systems appears to come "online" for handing this

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and is known as the novelty-routinization principle (Goldberg 2009). This novelty-routinization principle exemplifies a dynamic view of the brain function that provides us with one way of understanding the changing underlying neuroanatomical and neuropsychological events that occur during learning and skill development (Koziol 2014). These hemispheric asymmetries are thought to support different styles of information processing.

The right hemisphere processes information in a simultaneous holistic manner, whereas the left hemisphere processes information in an analytic, successive manner. This allows for the acquisition of harmonizing information about the world. Hence, these two modes of processing provide more robust information, different than what would be obtained from one type of processing in isolation. The brain is far more complex than this simple dichotomy, however. The great neuropsychologist Alexander Luria, in several of his writings (Luria 1966, 1980, 1982), maintained that the brain is complex and that no part of it functions without the cooperation of other parts. Thus, Luria viewed the brain as a functional mosaic, meaning that various parts interact in different combinations to apply varying combinations of cognitive processing abilities (Luria 1973). Thus, Luria contended that there is no area of the brain that functions without input from other areas. Integration of processing abilities is a key principle of brain function within the Lurian framework.

During the past decade, ideas about the functional specialization of brain regions have dramatically evolved. According to Johnson and colleagues (2005) and Friston (2002), functional specialization can be defined as the degree of information processing specificity of an identified brain region for a particular cognitive ability or facet of cognitive operations. However, as Luria pointed out, brain regions obviously do not function in isolation. The functional architecture of the brain is characterized by reciprocal connectional brain profiles of the cerebro-cortical, cortical-basal ganglia, cerebro-cerebellar, and basal ganglia-cerebellar circuitry systems (Bostan, A. C., Dum, R. P., & Strick, P. L. 2010, 2013; Bostan and Strick 2010; Koziol et al. 2011).

The importance of understanding neurocognitive processing allows us to understand not only the dynamic nature of the brain but also allows us to understand differences in learning and skill development. Technologies such as magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), positron emission tomography (PET), computerized tomography (CT), and diffusion tensor imaging (DTI) have reduced the need for neuropsychological tests to localize and access brain damage. Although these technologies are favored for investigating the structural and functional dynamics of the brain, it is these authors' opinion that the understanding and assessment of neurocognitive processes by studying patterns of neurocognitive strengths and weaknesses in developmental, psychiatric, psychosocial, and learning disorders are best achieved through formal assessment procedures. By addressing both brain functions and environmental factors intrinsic in complex behaviors, such as thinking, reasoning, planning, and the variety of executive capacities, clinicians are able to offer needed services to children with a variety of learning, psychiatric, and developmental disorders. Several neuropsychological tests play an important role in identifying the neurocognitive processes, or abilities, necessary for effective thinking, learning, and behaving, while also allowing for judgments regarding the integrity of the brain. Psychologists of different specialties may use standardized instruments to collect information and derive inferences about brain-behavior relationships. Traditional neurocognitive testing and evaluation takes a cortical-centric approach to understanding brain-behavior relationships. Neuropsychological tests can also be utilized as one way to assess the integrity of cortical-subcortical functional networks such as the fronto-striatal system, among others (Koziol 2009). Consistent with current functional conceptualizations of the brain, we believe both cortical and subcortical networks are important for basic neuropsychological processes to manifest efficiently.

A conceptualization of human cognitive functioning like the one described by A. R. Luria can guide the development of assessment tools. Such tools should not only evaluate the underlying neurocognitive processes necessary for efficient thinking and behavior but also provide for the development of effective interventions and address the question of prognosis.

Neuropsychological Theory and PASS Processes

Luria's theoretical account of dynamic brain function is perhaps one of the most complete (Lewandowski and Scott 2008) and current research in the area of large neuro-networks continue to lend support to his original observations (Koziol 2014). Luria conceptualized four unified levels of brain-behavior relationships and neurocognitive disorders that the clinician needs to know: the structure of the brain, the functional organization based on structure, syndromes and impairments arising in brain disorders, and clinical methods of assessment (Korkman 1999). His theoretical formulations, methods, and ideas are articulated in works such as *Higher Cortical Functions of Man* (1966, 1980) and *The Working Brain* (1973). Luria viewed the brain as a functional medley, the parts of which interact in different combinations to subserve cognitive processing (Luria 1973). Cognition and behavior then result from an interaction of complex brain activity across various areas. Luria's (1966, 1973, 1980) research on the functional aspects of brain structures formed the basis for the development of the PASS theory (planning, attention, simultaneous, successive processing), initially described by Das et al. (1994) and operationalized by Naglieri and Das (1997a, b) in the *Cognitive Assessment System* (CAS), and most recently in the Cognitive Assessment System-Second Edition (Naglieri et al. 2014a, b).

From a Lurian framework, cognitive functions, such as attention, executive functions, language, sensory perception, motor function, visuospatial facilities, and learning and memory, are multifaceted capacities. They are composed of flexible and interactive subcomponents that are mediated by equally flexible, interactive, neural networks (Luria 1962, 1980). These cognitive functions are theorized as three separate but connected "functional units" that provide four basic psychological processes. The three brain systems are referred to as "functional" units because the neuropsychological mechanisms work in separate but interrelated systems. In other words, multiple brain systems mediate complex cognitive functions. For example, multiple brain regions interact to mediate attentional processes (Koziol, Joyce, & Wurglitz, 2014). The executive functions subserved by the third functional unit, as described by Luria, regulate the attentional processes of the first functional unit in sustaining the appropriate level of arousal and vigilance necessary for the detection and selection of relevant details from the environment. Consider the case of response inhibition; the executive function of inhibition allows a student to resist or inhibit responding to salient, but irrelevant, details on a task. Response inhibition allows the student to sustain focus, over time, on task relevant features.

The brain systems described above are consistent with the four psychological processes identified by the PASS theory (Naglieri and Das 1997b), and this amalgamation of processing abilities is a key principle of brain function within the Lurian framework. Cognition and behavior result from an interaction of complex brain activity across various areas. Naglieri and Das (1997a, b) used Luria's work as a base to redefine intelligence from a multi-ability perspective. The PASS theory has strong empirical support (see Das et al. 1979, 1994b) and since the publication of the Cognitive Assessment System (CAS) and Cognitive Assessment System-Second Edition (CAS-2) (see Naglieri 2012; Naglieri and Conway 2009; Naglieri and Otero 2011).

Luria (1973) stated "each form of conscious activity is always a complex functional system and takes place through the combined working of all three brain units, each of which makes its own contribution" (p. 99). In other words, the four processes form a "working constellation" (Luria 1966, p. 70) of cognitive activity. Thus, a child or adult can use different combinations of the four psychological processes in conjunction with their knowledge and skills to perform a task. Although effective functioning is achieved through the appropriate combination of all processes as demanded by the task, each process is not equally involved in every task. For example, reading comprehension may predominately involve one process, while reading decoding can be strongly dominated by another (Das et al. 1994b). Or basic math calculation may require more of one process, while math-reasoning tasks may require a different cognitive process. For example, learning basic math calculation operations may initially require a basic step-by-step approach. Understanding math-reasoning problems, however, requires holding multiple elements of the task in memory, surveying the elements, and making decisions about these elements before solving the problem. Das and Naglieri and their colleagues used Luria's work as a blueprint for defining the basic neuropsychological processes that underlie human performance (Naglieri 2003). Their efforts represent the first time that a specific researched neuropsychological theory was used to provide an alternative conceptualization of human intelligence.

Three Functional Units Described

Luria (1973) provided considerable evidence for the neuropsychological processes associated with each of the three functional units and their association with specific regions of the brain. Briefly stated, these three functional units have been used by Naglieri and Das (1997b) as the basis of planning (third functional unit), attention (first unit), and simultaneous and successive (second unit) cognitive processes. The brain stem, the diencephalon, and the medial regions of the cortex are the primary locations for the first of the three functional units of the brain, the attention-arousal system, (Luria 1973). This unit is comprised specifically of the midbrain, medulla, thalamus, and hypothalamus. These structures work in concert to maintain the appropriate cortical tone. Recent formulations of these regions suggest some structures at the level of diencephalic and medial regions have reciprocal connections to the cortex through a variety of large-scale brain circuitries (Koziol and Stevens 2012) potentially influencing a wide range of behaviors (Koziol 2009).

First Functional Unit

Attention is a basic component of intelligent behavior involving allocation of resources and effort. Arousal, attention, effort, and capacity are concepts that have a complex relationship and importance for understanding behavior. When a person is required to pay attention to only one dimension of a multidimensional stimulus array, the inhibition of responding to other (often more salient) stimuli and the allocation of attention to the central dimension are required. Luria stated that optimal conditions of arousal are needed before the more complex forms of attention involving "selective recognition of a particular stimulus and inhibition of responses to irrelevant stimuli" (Luria 1973, p. 271) can occur. This way of conceptualizing attention is analogous to such contemporary models as Mirsky and Duncan's (2001, 2003; Koziol 2014) in which focus, shift, sustenance, and stabilization of attention are necessary before complex learning can take place. Moreover, the second and third functional units can operate effectively only after individuals are sufficiently aroused and their attention is adequately focused.

Second Functional Unit

The occipital, parietal, and temporal (particularly medial temporal portions) lobes posterior to the central sulcus of the brain are associated with the second functional unit. Information from the external world is received, processed, and retained within this unit. Thus, the major function of the second functional unit is sensory reception and integration (Semrud-Clikeman and Teeter Ellison 2009). The areas of the second functional unit correspond to their sensory modality: temporal for auditory stimuli, parietal for tactile, and occipital for visual. This functional unit is hypothesized to be guided by three functional laws: (1) during development, the makeup of cortical zones does not remain the same; (2) the specificity of function of the cortical zones decreases with development; and (3) an increase in lateralization of function increases with development (Luria 1980). This hierarchy is further subdivided into *zones*. The primary zones of these structural units employ modality-specific groups of neurons to receive impulses from the sensory organs, while the secondary zones of these structures surround the primary zones with associative neurons which enable incoming excitation to be conveyed to the tertiary zones. These tertiary zones are responsible for integrating and organizing the excitation arriving from the different sensory structures and converting the stimuli which are received in a specific linear order into simultaneously processed groups (Luria 1974). The secondary zones are involved in the input of data and integration of information. These zones process information sequentially and connect cross-modally with several stimuli impinging on the brain at a time. For example, reading is an integration of both visual and auditory material, and mathematics is the integration of visual material with the knowledge of numbers and quantity.

There are several secondary zones for auditory, tactile, and visual information. The auditory secondary zone lies within the secondary regions within the temporal lobes and involves the analysis and synthesis of sounds and the sequential analysis of phonemes, pitch, tone, and rhythm. The secondary tactile zone is within the parietal lobe and is involved in the recognition of complex tactile stimuli and two-point discrimination, for example. The secondary visual zone borders the primary visual cortex of the occipital lobe. Visual discrimination of letters, shapes, and figures are related to it. Traditional intelligence tests are hypothesized to measure some aspects of the second functional unit (Semrud-Clikeman and Teeter Ellison 2009). Because the second functional unit can be considered as the center for analysis, coding, and storage of information, damage to the structures forming the second functional unit can result in difficulty across all academic areas.

Tertiary zones process and integrate information from all sensory areas. This integration of information from various modalities occurs through simultaneous processing. For example, some math involves the integration of both visual materials and knowledge of number quantity. Math reasoning, in the form of word problems, may additionally involve the integration of grammatical skills, analysis of auditory information, and the comprehension of auditory or written material. Damage to these zones has been related to lower measured intelligence and difficulties across several basic academic areas.

Simultaneous and successive processing are subserved by the second functional unit. Simultaneous processing is a mental activity by which a person integrates stimuli into interrelated groups or a whole. For example, in order to follow multistep directions, the relationships among the different parts of what is said must be correctly understood. Reading unfamiliar words that are initially difficult to decode and then are later quickly and effortlessly recognized as a whole word is another example of a task initially demanding successive processing, followed by the efficient simultaneous processes of reading the word as a whole unit. Children presenting with difficulties performing on tasks that require learning new information by associating it with other information may have deficits in simultaneous processing. Difficulty integrating visual information may be a primary deficit in children with nonverbal learning disabilities. These children have been found to do more poorly on measures that demand simultaneous processing such as tests on visual motor integration and visual-perceptual skills compared to children with ADHD and normally developing children (Wilkinson and Sermund-Clikeman 2008).

While simultaneous processing involves working with interrelated stimuli, successive processing *requires* work with stimuli in a specific serial order. This processing ability is required when a child arranges things in a strictly defined order, where each element is only related to those that precede it and these stimuli are not interrelated.

Successive processing ability involves both the perception of stimuli in sequence and the formation of sounds and movements in order. For example, successive processing is involved in the decoding of unfamiliar words, production of syntactic aspects of language, and speech articulation. Following a sequence such as the order of operations in a math problem is another example of successive processing. Most real-life situations will require both of these processes to become activated to some degree.

Third Functional Unit

One of the most extraordinary capacities we have as humans is our ability to reflect and self-direct behavior. This ability is frequently described using the term executive function (EF). Although many definitions of EF abound (Goldstein et al. 2014), the concept of EF is intimately linked to the frontal lobes. The prefrontal areas of the frontal lobes of the brain are associated with the third functional unit (Luria 1980). The prefrontal cortex is well connected with every distinct functional unit of the brain (Goldberg 2009). This unit is mostly responsible for output planning and with most behaviors we typically consider as executive functions. The third functional unit is also further differentiated into three zones, with the primary zone in the motor strip of the frontal lobe being concerned with motor output. The secondary zone is responsible for the sequencing of motor activity and speech production, while the tertiary zone is primarily involved with behaviors typically described as executive functions. Damage to any of several areas of the frontal regions has been related to difficulties with impulse control, learning from one's mistakes, delay of gratification, and attention. Because the third functional unit has rich connections with other parts of the brain, both cortical and subcortical, there can be forward and backward influences, to and from other regions such as the cerebellar, thalamic, hypothalamic, and limbic areas. Additionally, a growing body of evidence points to a network of connected regions in the adjacent frontal and parietal lobes, which have been implicated in higher-order processing such as attention, decision-making, and intelligence (Kolb and Whishaw 2009).

Luria stated that "the frontal lobes synthesize the information about the outside world … and are the means whereby the behavior of the organism is regulated in conformity with the effect produced by its actions" (Luria 1980, p. 263). The frontal lobes provide for the programming, regulation, and evaluation of behavior and enable a person to ask questions, develop strategies, and self-monitor (Luria 1973). Other responsibilities of the third functional unit include the regulation of voluntary activity, conscious impulse control, and various linguistic skills such as spontaneous conversation. The third functional unit provides for the most multifaceted aspects of human behavior, including personality and consciousness (Das 1980). The first and third functional units share a reciprocal relationship. The higher cortical systems both regulate and work in collaboration with the first functional unit while also receiving and processing information from the external world and determining an individual's dynamic activity (Luria 1973). It is both influenced by the regulatory effects of the cortex and influences the tone of the cortex. The ascending and descending systems of the reticular formation enable this relationship by transmitting impulses from the lower parts of the brain to the cortex and vice versa (Luria 1973). Thus, damage to the prefrontal area can alter this reciprocal relationship, so that the brain may not be sufficiently aroused for complex behaviors requiring sustained attention. A breakdown in any portion of the complex loop-like interactions between the prefrontal, ventral brain stem and posterior cortex is likely to produce symptoms of attention deficit (Goldberg 2009).

The psychological processes that are routed in each of the functional units are linked. For the PASS theory, this means that psychological processes of attention and planning are strongly related because planning often has conscious control of attention. In other words, one's limited attentional resources are dictated by the plan for one's behavior. However, attention as well as the other PASS processes are influenced by many variables other than planning. One of these influences is the environment. Novel encounters within daily life demand we act in one way or another. Several PASS processes can be involved as we make judgments about similarities and differences between past situations and the present demands, while hypothesizing possible outcomes of our actions and as we select behaviors while acting on the environment.

Functional Units: Interactions and Influences

Luria believed no part of the brain works by itself, and therefore, his organization of the brain into functional units was not an attempt to map out the precise locations where specific areas of higher cognition took place, but rather to emphasize that no cognitive task solely requires simultaneous, successive, planning, or attention processing or any other process, but rather, it is a matter of emphasis. He stated, "…perception and memorizing, gnosis and praxis, speech and thinking, writing, reading and arithmetic, cannot be regarded as isolated or even indivisible 'faculties'…" (Luria 1973, p. 29). That is, an attempt to identify a fixed cortical locale for any complex behavior is a mistaken endeavor. Instead, the brain should be conceptualized as a functioning whole comprised of units that provide purpose.

Activities such as reading and writing can be evaluated and seen as constellations of activities related to specific working zones of the brain that support them (Luria 1979). This means that since the brain operates as an integrated functional system, even a minor disruption in an area can cause disorganization in the entire functional system (Varnhagen and Das 1986). Thus, many behaviors may be impacted by a disruption caused by a lesion, damage, or underdeveloped structures. For example, lesions or damage to the prefrontal cortex, with its complex connections with other areas of the brain including several subcortical areas, may result in affective dissociations, impaired executive functions, poor judgment and processing, or intellectual deficits.

Luria believed that a child's cultural experience is a significant influence on the functional units and also a necessary foundation that aids the development of human cognition (Luria 1979). The organization of the brain into functional units also accounts for the interaction of cultural influences and biological factors within higher cognition. Luria (1979) notes "…the child learns to organize his memory and to bring it under voluntary control through the use of the mental tools of his culture" (p. 83). Kolb et al. (2003) also wrote that although "the brain was once seen as a rather static organ, it is now clear that the organization of brain circuitry is constantly changing as a function of experience" (p. 1). Various brain systems are highly modifiable by experience and dependent on experience only during particularly sensitive time periods and other systems remain capable of change by experience throughout life (Neville 2006; Neville and Stevens 2008). Similarly, Vygotsky (1976) described this interplay when he described speech as a self-regulatory function. Self-talk functions as self-guidance and regulation, helps children think about their mental activities and behaviors, and select courses of action, and is the foundation for all higher cognitive processes (e.g., controlled attention, deliberate memorization and recall, categorization, planning, problem-solving, abstract reasoning, self-reflection). Stuss and Benson (1990) described this interplay as follows:

> The adult regulates the child's behavior by command, inhibiting irrelevant responses. His child learns to speak, the spoken instruction shared between the child and adult are taken over by the child, who uses externally stated and often detailed instructions to guide his or her own behavior. By the age of 4 to 4 ½, a trend towards internal and contract speech (inner speech) gradually appears. The child begins to regulate and subordinate his behavior according to his speech. Speech, in addition to serving communication thought, becomes a major self-regulatory force, creating systems of connections for organizing active behavior inhibiting actions irrelevant to the task at hand. (p. 34)

Culture influences the development of higher cognitive functioning through a variety of different channels. Luria (1979) emphasized the importance of the frontal lobes in language, organization, and direction of behavior and speech as a cultural tool that furthers the development of the anterior brain region and self-regulation. Cultural experiences accelerate the use of planning and self-regulation and the other cognitive processes. Luria (1979) suggested that abstraction and generalizations are themselves products of the cultural environment. Children learn, for example, to selectively pay attention to items that are pertinent through conversations and playful interactions with adults. Even simultaneous and successive processes are influenced by cultural experiences (e.g., learning dances, poems, game rules, and so on). Naglieri (2003) summarized research that showed that the influence of social interaction on children's use of plans and strategies resulted in improvements in performance on academic tasks. Luria's concept of functional units and their relationship to the larger sociocultural context provides the foundation for the PASS theory.

From Luria to PASS Theory of Intelligence

The four processes in the PASS theory represent a fusion of cognitive and neuropsychological constructs including executive functioning (planning); selective, sustained, and shifting attention (attention); visual-spatial tasks (simultaneous); and serial features of language and memory (successive) (Naglieri and Das 2005). These four processes are more fully described in the sections that follow.

The human ability to plan differentiates humans from other primates. Planning is associated with the prefrontal cortex. The prefrontal cortex "plays a central role in forming goals and objectives and then in devising plans of action required to attain these goals. The cognitive processes required to implement plans, coordinate these activities, and apply them in a correct order are subserved by the prefrontal cortex. Finally, the prefrontal cortex is responsible for evaluating our actions as success or failure relative to our intentions" (Goldberg 2009, p. 23). Planning helps one to achieve goals through the development of strategies necessary to accomplish tasks for which a solution is required. Therefore, planning is an essential ability to all activities that demand the child or adult to figure out how to solve a problem. This includes self-monitoring and impulse control as well as making, assessment, and implementation of a plan. Thus, planning allows for the generation of solutions, discriminating use of knowledge and skills, as well as control of attention, simultaneous, and successive processes (Das et al. 1996).

The essential dimension of the construct of planning as defined by Naglieri and Das (1997b) is very similar to the description of executive function provided by others (see Naglieri and Goldstein 2006). For example, O'Shanick and O'Shanick (1994) describe executive functions as including the abilities to formulate and set goals, assess strengths and weaknesses, plan and/or direct activities, initiate and/or inhibit behavior, monitor current activities, and evaluate results. Executive functions include abilities to formulate a goal, to plan, to carry out goal-directed behaviors effectively, and to monitor and self-correct spontaneously and reliably (Lezak et al. 2012). McCloskey et al. (2009) identify two key dimensions that unify several diverse definitions of executive functions. To some degree, all definitions address components that direct and cue other processes, and all address functions that link activation to the frontal lobe regions. These skills are essential for fulfilling most daily responsibilities and maintaining appropriate social behavior. A variety of assessment tools that have been proposed to assess executive functions often yield conflicting data given the very broad definition of these functions (e.g., for a review of this issue in the assessment of ADHD, see Barkley 2006). Planning in the PASS theory offers a more finite description that may be characterized as executive function.

Attention is a cognitive process that is closely connected to the orienting response. Attention, as ability, allows a person to demonstrate focused, selective cognition over time, with resistance to distraction. Attention occurs when a person selectively focuses on particular stimuli and inhibits responses to competing stimuli. The process is involved when we must demonstrate focused, selective, sustained, and effortful activity. *Focused* attention involves concentration directed toward a particular activity, and *selective* attention is important for the inhibition of responses to distracting stimuli. *Sustained* attention refers to the variation of performance over time, which can be influenced by the varying amounts of effort required to solve a task. Brain structures within Luria's first functional unit, the reticular formation, allow one to focus selective attention toward a stimulus over a period of time without the loss of attention to other competing stimuli. The longer attention is needed, the more the activity necessitates vigilance. Intentions and goals mandated by the planning process control attention, while knowledge and skills play an integral part in the process as well. The attention work of Schneider et al. (1984) and the attention selectivity work of Posner and Boies (1971), which relates to deliberate discrimination between stimuli, are similar to the way that the attention process is conceptualized. Planning processes regulate a variety of other processes, including attention.

Simultaneous processing is necessary for synthesizing separate elements into a cohesive whole or interrelated group. The ability to recognize patterns as interrelated elements is made possible by the parieto-occipital-temporal brain regions. Due to the substantial spatial characteristics of most simultaneous tasks, there is a visual-spatial dimension to activities that demand this type of process. Conceptually, the examination of simultaneous processing is achieved using tasks that could be described as involving visual-spatial reasoning, found in progressive matrices tests like those developed by Penrose and Raven (1936). Simultaneous processing is not, however, limited to nonverbal content, as demonstrated by the important role it plays in the grammatical components of language and comprehension of word relationships, prepositions, and inflections (Naglieri 1999). This is most apparent in the inclusion of the verbal-spatial relationship subtest in the CAS (Naglieri and Das 1997a). Typically, however, matrices tests have been included in the so-called nonverbal scales of intelligence tests such as the *Wechsler Nonverbal Scale of Ability* (Wechsler and Naglieri 2006), the perceptual reasoning portion of the *Wechsler Intelligence Sale for Children-IV* (WISC-IV; Wechsler 2003), the *Stanford-Binet Fifth Edition* (SB5; Roid 2003), the *Naglieri Nonverbal Ability Test* (NNAT; Naglieri 1997), and the *Kaufman Assessment Battery for Children, Second Edition* (KABC-2; Kaufman and Kaufman 2004) and as a simultaneous processing test (Naglieri and Das 1997a, b).

Successive processing is relevant when working with stimuli arranged in a defined serial order such as remembering or completing information in compliance with a specific order. Successive processing is typically an essential element involved with the serial organization of sounds, such as learning sounds in sequence and early reading. Furthermore, successive processing has been conceptually and experimentally related to the concept of phonological analysis (Das et al. 1994b). When serial information is grouped into a pattern, however, (like the number 553669 organized into 55-3-66-9), then successful repetition of the string may be a function of another cognitive processes, such as planning (i.e., using the strategy of chunking) and simultaneous (organizing the numbers into related groups). This method is often used by older children and can be an effective strategy for those who are weak in successive processing (see Naglieri and Pickering 2003). In clinical practice, we have observed that young children with poor successive processing often have difficulty following directions or comprehending what is being said to them when sentences are too lengthy. Teachers and parents often misinterpret this weakness as a failure to comprehend or as a problem of attention.

Traditionally, intelligence is measured through verbal, nonverbal, and quantitative tests, yet the PASS theory offers an alternative approach to intelligence. This theory broadens the idea of what abilities should be measured and also emphasizes the significance of basic neurocognitive processes. Additionally, the functional units of the brain that encompass the PASS processes are considered the building blocks of ability conceptualized within a neurocognitive processing framework. While the theory may have its roots in neuropsychology, "…its branches are spread over developmental and educational psychology" (Varnhagen and Das 1986, p. 130). Thus, with its connections to developmental and cognitive processing, the PASS theory offers an advantage in explanatory power over the notion of general intelligence (Naglieri and Das 2002).

Measuring PASS Processes

The PASS theory was operationalized by the CAS (Naglieri and Das 1997a; Naglieri et al. 2014a, b). This instrument is thoroughly described in the CAS-2 interpretive handbook (Naglieri et al. 2014b). Naglieri et al. (2014a, b) generated tests to measure the PASS theory following a systematic and empirically based test development program designed to obtain efficient measures of the processes for individual administration. The PASS theory was used as the foundation of the CAS, so the *content of the test was determined by the theory* and not influenced by previous views of ability. The CAS-II (Naglieri et al. 2014a, b) is a Lurian-based test of cognitive abilities and processing that is highly predictive of academic learning and very useful in identifying processing strengths and weaknesses. The CAS-II, normed for ages 5–18, is supported by research linking the CAS-II processes with specific types of learning (Naglieri and Das 1997a, b) and research linking specific-processing deficits with specific learning disabilities. The four CAS-II composites are intended to measure planning, attention, simultaneous processing, and successive processing. The CAS-II composites and all of the subtests can be categorized as measures of cognitive processing. The CAS-II does not contain any measures of verbal knowledge or crystallized intelligence (see Chapter XXX for a thorough presentation of the CAS-II).

Validity

Using Luria's neuropsychological framework of three functional units, Das (1972) and Das et al. (1975, 1979, 1994b) began the task of figuring out methods for measuring the PASS processes. These efforts included extensive analysis of the methods used by Luria, related procedures used within neuropsychology, experimental research in cognitive and educational psychology, and related areas. Their work was summarized in several books by Kirby (1984); Kirby and Williams (1991); Das et al. (1994b); Naglieri (1999); and Naglieri et al. (2014a, b), which provide considerable evidence that the PASS processes associated with Luria's concept of the three functional units could be measured and that once measured, these processes have considerable reliability and validity. Their work also demonstrated that there was significant potential for the application of the theoretical conceptualization of basic psychological processes. The remainder of this section will provide a summary of relevant validity research on the PASS theory as operationalized by the CAS.

Relationship to Achievement

One of the purposes of an ability test is to determine a child's level of cognitive functioning that can then be used to anticipate performance in a number of contexts, such as school. Some have noted that the relationship between a test of ability and achievement is perhaps one of the most important aspects of validity (Brody 1992; Cohen et al. 1992; Naglieri and Bornstein 2003). For many years, researchers have studied the relationship between ability and achievement. Well-known IQ tests often include measures of vocabulary, general information, and arithmetic, as do tests of achievement. It is no surprise then that the relationship between ability and intelligence has been found to be about 0.55–0.60 (Brody 1992; Naglieri 1999). It has been argued, however, that a portion of the correlation between traditional IQ tests and academic achievement tests is due to the similarity in content that exists between these two types of tests (Naglieri and Bornstein 2003; Naglieri and Rojahn 2004). Given that the CAS does not include test items that are typically part of traditional IQ tests such as vocabulary and arithmetic, how well does it correlate with achievement?

Naglieri and Rojahn (2004) studied the relationship between the PASS processing scores of the CAS with the *Woodcock Johnson-Revised Tests of Achievement* (WJ-R; Woodcock and Johnson 1989) with a sample of 1,559 students aged 5–17 years. The correlation between the CAS Full Scale and the WJ-R Tests of Achievement was 0.71 for the standard (all 12 subtests) and 0.70 for the basic battery score (eight subtests). These findings provide evidence for the construct validity of the CAS and more importantly suggest that basic psychological processes are strongly related to academic performance as measured by this standardized test of achievement.

Naglieri et al. (2006) compared the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler 1991) to the CAS and the Woodcock-Johnson III Tests of Achievement (WJ-III-ACH; Woodcock et al. 2001) with a sample of children aged 6–16 who were referred for evaluation due to learning problems. The correlation of the WJ-III-ACH scores with the WISC-III Full Scale IQ scores was 0.63 and 0.83 with the CAS Full Scale. However, the CAS Full Scale scores correlations were significantly higher (Naglieri et al. 2006).

The findings provide evidence for the construct validity of the CAS and suggest that basic psychological processes are strongly correlated with academic performance and are especially important because the measures of the PASS processes do not include achievement-like subtests (e.g., vocabulary and arithmetic). This provides considerable advantage and is especially important for children who come from disadvantaged environments as well as those who have had a history of academic failure.

Importantly, Naglieri and Rojahn (2004) also found that prediction of achievement was slightly higher for the four PASS Scales than the CAS Full Scale. These findings suggested that the four PASS Scales individually and collectively correlate higher with achievement than the four scales aggregated into the one Full Scale score. Additionally, the predictive power of the combination of the four PASS Scales was weakened when any one of the PASS Scales was excluded in the prediction equation (Naglieri and Rojahn 2004). This suggests that each of the PASS Scales has additive value in predicting achievement and further supports the notion of interrelated neurocognitive processes within the Luria's framework of functional units.

Relationship to Behavior

Limited research has been conducted specifically examining the relationship of PASS processes to behavior. Clinically, the connection between PASS processes and a child's behavior is often observed. For example, successive processing involving the ability to follow information in a linear organization or chainlike progression will exert a significant impact on a child's behavior. Planning processing involves the ability to focus one's thinking, attend and screen out distractions which is essential for children to play effectively with others on the playground, and interact with adults, as well as a variety of real-life tasks.

Several researchers have examined the relationship between the behavioral difficulties seen in children with ADHD and PASS profile scores. For example, Paolitto (1999) studied matched samples of ADHD and normal children. Children with ADHD earned significantly lower scores on the planning scale. Similarly, Dehn (2000) and Naglieri et al. (2003) found that groups of children who met diagnostic criteria for ADHD earned significantly lower mean scores on the planning scale of the CAS. These results support the view that ADHD involves problems with behavioral inhibition and self-control, which is associated with poor executive control (Planning; Naglieri and Goldstein 2006). These findings suggest that the PASS processing theory has utility for differential diagnosis, intervention, as well as response to intervention for behavioral problems (Naglieri 2003, 2005).

The measurement of cognitive processes using the Cognitive Assessment System (CAS) has been utilized with individuals who suffer from traumatic brain injury (TBI). Due to the fact that cognitive impairments and deficits are very common in individuals with TBI, the CAS is a measure that can be used to assess the cognitive processes of this population. According to Luria (1973), when one suffers severe brain damage, it is likely that he or she will also experience impairments in such processes as organization and planning (as cited in Gutentag et al. 1998). One of the main reasons as to why an assessment tool such as the CAS would be particularly useful for the TBI population is because typical intelligence tests only yield results that reflect one's general intelligence; they do not provide measurement of basic psychological processes. For example, deficits in attention and planning that interfere with the academic performance of children with TBI (Savage and Wolcott 1994) must be measured. Gutentag et al. (1998) studied children with TBI showed deficits on the CAS compared to a matched control group drawn from the CAS normative population. Neurocognitive deficits were most pronounced in the attention and planning domains and less severe in the simultaneous and successive domains (Gutentag et al. 1998, p. 265).

Fairness

The CAS has been increasingly used across cultures and languages. In Spain for example, Perez-Alvarez et al. (2006) used the CAS in a study assessing the effects of topiramato (a pharmacological treatment for epilepsy) on cognitive processes and behavior. The 35 patients ranging in age from 5 to 15 years were assessed with the CAS at baseline and again at 6 and 12 months. The parents were given behavior-rating scales at each interval as well. At baseline, 6 and 12 months, patients had lower successive scores. At 12 months, planning scores had increased significantly, while there was a concomitant improvement on behavior as measured by rating scales. Mccrea (2009) studied three patients with unilateral focalized stroke lesions longitudinally on the CAS subtests at 1 month and 6 months post infarct, such that each patient functioned as their own baseline. Patient 1 with a left temporal pole lesion had a severe syntactic comprehension deficit on sentence questions. Patient 2 had a rare right anterior cerebral artery (ACA) aneurysm culminating in an orbitofrontal syndrome and impairments on expressive attention, word series, as well as a praxis-based figure ground reversal phenomenon on figure memory. Patient 3 suffered a right frontoparietal lesion with resulting representational as well as elements of motor neglect and impairments on matching numbers, number detection, and receptive attention. Each patient's lesions were all entirely consistent with the nature of cognitive neuropsychological symptoms suggesting that the CAS subtests are unique and also sensitive and specific to focalized cortical lesions.

The characteristics of the US population continue to change with every census, and the need for fair assessment of children has become progressively more important. Traditional IQ tests have items that measure content that is dependent on exposure to the dominant culture, language, and formal education. This content can create an unfair disadvantage for many children, such as those living in non-English-speaking homes and impoverished environments. Reducing the amount of knowledge needed to correctly answer the questions on intelligence tests is a useful way to ensure appropriate and fair assessment of diverse populations. Some researchers have suggested that conceptualizing intelligence as a set of psychological processes, such as the PASS theory as operationalized by the CAS, has utility for assessment of children from culturally and linguistically diverse populations because verbal and quantitative skills are not included (Naglieri and Otero 2011; Naglieri et al. 2005, 2007).

Several researchers have found up to a 15-point mean difference between Blacks and Whites on traditional tests of cognitive ability.

Results for PASS processing tests have shown only small differences between these groups. For example, Naglieri et al. (2005) compared CAS scores of a sample composed of 298 Black children and 1,691 White children. Controlling for key demographic variables, regression analyses showed an estimated CAS Full Scale mean score difference of 4.8, which is smaller than that found with traditional tests of ability. Another finding was that correlations between the CAS scores and WJ-R Tests of Achievement were very similar for Blacks (0.70) and Whites (0.64; Naglieri et al. 2005). Naglieri et al. (2006) examined CAS scores for 244 Hispanic and 1,956 non-Hispanic children. They found that the two groups differed by 6.1 points when the samples were unmatched samples, 5.1 with samples matched on basic demographic variables, and 4.8 points when demographic differences were statistically controlled. These findings further demonstrate the utility of PASS theory as one way to fairly assess diverse populations.

When evaluating the cognitive ability of English language learners, psychologists currently have three practice options (Ortiz 2009). These methods are (a) modifications and adaptations of the standardized administration and scoring of the test; (b) the selection and use of specific tests or battery of tests that are of a nonverbal nature; and (c) the use of a more traditional native language-based test (e.g., WISC-IV Spanish). Each method has its limitations and advantages. The first method, modifying or adapting the tests in terms of administration or scoring, violates standardization directly, resulting in error and in less reliability and validity of scores attained. The second method, and perhaps the most commonly practiced (Ortiz 2009), involves the use of a nonverbal battery or the administration of select subtests that make up the PIQ (Figueroa 1990), or more recently, the PRI. This method, although it reduces the impact of language on test results, would not be helpful in cases in which the student's dysfunction is actually language based (such as reading or written language). The third option, the use of a native language test, may seem to be the ideal option with ELL students. However, these tests fail to control for the level of language proficiency (Harris and Llorente 2005).

In the case of ELL Hispanic children, Naglieri et al. (2007) compared the English and Spanish versions of the CAS for bilingual Hispanic children. The children in this study earned very similar CAS Full Scale scores, and deficits in successive processing were found on both versions of the test. Importantly, 90 % of children who had a neurocognitive weakness on one version of the CAS also had the *same* neurocognitive weakness on the other version of the CAS. Otero et al. (2013) examined the performance of referred Hispanic English Language Learners of varying proficiency levels ($N=40$) on the English and Spanish versions of the *CAS* and found no significant differences between the Full Scale scores or in any of the PASS scales. Students earned their lowest scores in successive processing regardless of the language in which the test was administered. These findings suggest that the *CAS* may be a useful measure for Hispanic children with underdeveloped English language proficiency. These results suggest that the PASS scores from both the English and Spanish version of the CAS could be used as part of a comprehensive evaluation.

Conclusions

Although several definitions of intelligence have been set forth for over a century, the definition of intelligence as a constellation of neurocognitive processes such as planning, attention, simultaneous, and successive processes is unique and theory driven. There is a growing need for neurocognitive measures to evaluate and explain function, facilitate prognosis, and most importantly guide intervention. Luria's PASS theory offers a blueprint for defining the basic neurocognitive processes underlying human performance, behavior, and intelligence. Appreciation and application of this processing model as a framework for assessment provides psychologists with an essential tool necessary to not just understand children's learning and behavior but to guide and develop effective intervention. The PASS theory as operationalized by the CAS-2 provides a well-developed tool for assessment of the four basic psychological processes described by Luria. The importance of assessing PASS neurocognitive processes cannot be overemphasized in light of the evidence of its use with various groups, including Hispanic English language learners.

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CHC Theory of Intelligence

15

Samuel O. Ortiz

The concept of intelligence is as ubiquitous as any other artifact of our culture. It is a word that is used often, readily accepted in meaning, and used to invoke explanations for all sorts of social and behavioral phenomena observed and encountered on a daily basis. It is found frequently in all forms of popular and professional literature and discourse and is a common topic in introductory science texts across myriad specialties and related disciplines, particularly psychology. Even the term born from the idea of intelligence, "IQ" (or "intelligence quotient"), is no longer an acronym per se but an accepted word in all modern language dictionaries including the one that even governs the official rules of the game, Scrabble. Unquestionably, we can point to few things in modern life that can claim to be so familiar, so well known, and so much a part of our daily experience as the notion of intelligence and our presumed understanding of it.

That intelligence is so ingrained in what we know value may also have done it a considerable disservice. Consider, for example, we all readily admit that we know exactly what it refers to, and thus rarely is anyone called upon to define it or its usage in a given context. Even less frequently is someone asked to defend the theoretical or empirical bases that would support its use in a given context. But when a situation requires a precise and scientifically validated definition, it is alarming to see both lay people and professionals scramble for support like rats on a sinking ship. Indeed, perhaps the most natural reaction in such cases is to invoke the one explanation provided by McNemar (1964) which is sure to appease everyone, where he noted "no definition is required because all intelligent people know what intelligence is—it is the thing the other guy lacks" (p. 871).

The focus of this chapter is not centered directly on intelligence. The purpose here is to describe the history and development of what is currently referred to as CHC theory, an acronym derived from the chronological order of contribution by the surname of its three main developers (i.e., Cattell, Horn, and Carroll). It is impossible, however, to discuss the development of the theory without addressing the debates surrounding the very notion and definition of intelligence, since any such theory must necessarily provide an explanation of it. And despite offering what is considered perhaps the most empirically validated and best supported theory of human cognitive abilities to date (e.g., Schneider and McGrew 2012), CHC theory is unlikely to be the first mention in response to any query regarding conceptualizations of intelligence. Admittedly, there has been an extraordinary and precipitous increase in published and unpublished research regarding CHC theory since 2000 (Schneider and McGrew 2012),

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but the reason why CHC theory remains in relative obscurity compared to other, more popular notions of intelligence (e.g., Spearman's *g*, Gardner's 'multiple intelligences') is an important part of its history and extremely relevant to its development. Likewise, because the theory itself carries the very names of its constituent authors, discussion of the one cannot be accomplished without discussion of the other.

CHC Theory and Cattell: Birth and the Early Years

The basic formulations of what would eventually become known as CHC theory began with Raymond B. Cattell (1941, 1943) whose academic pedigree in psychology could be traced back to his dissertation mentor, Charles Spearman, who himself was trained by Wilhelm Wundt. Born in 1905, it is important to recall and understand the time in which Cattell was attending school and how he was influenced heavily not only by his education and academic mentoring but also the values and beliefs of his culture and the prevailing zeitgeist. Having just missed military service in World War I, Cattell entered University College in London in 1921 studying chemistry primarily but then moving into psychology for graduate studies in 1925 at Kings College. Cattell had the good fortune of working with Spearman and completing his dissertation right around the time Spearman was refining the process of evaluating correlational data statistically in a manner that would eventually become known as factor analysis. Needless to say, Cattell was very well trained in this relatively new method and adopted not only the methodology from Spearman but a good deal of his philosophy as well. This included a strong belief in the genetic nature and determination of intelligence, ideas regarding the need for proactive policy with regard to individual's identified with low intelligence, and perhaps the most salient idea regarding his future career—a staunch acceptance of data analytic methods that provided a first-order general factor which was believed to represent *g* or general intelligence. It should be noted that Cattell's beliefs were no different than the vast majority of his fellow colleagues at the time, particularly his British counterparts whose historical class structure was justified on the basis of hereditary power stemming from hereditary attributes—particularly intelligence. Coupled with a society that was still actively engaged in colonialism, albeit wrestling with the notion more so than before and searching for scientific support to justify the practice, it is not surprising that Cattell's own early thoughts concerning intelligence differed little from his mentors or others at the time. What is truly remarkable about Cattell, however, was his willingness to modify his position and accept the mistakes and failings that characterized some of his early beliefs and theoretical conceptions when the data suggested otherwise. For example, in 1997 when Cattell was nominated and selected for the prestigious APA Gold Medal for Lifetime Achievement in the Science of Psychology, he was quickly accused of being a racist and condemned by a small faction who hinged their attack on Cattell's early thoughts on eugenics and theology as well as statements he made some 60 years prior and without any recognition of the manner in which his views evolved over the course of several decades. In an open letter to APA, he declined the award and, perhaps irrevocably heartbroken by the unfair portrayal, died several months later.

Whereas the label of racist might be fairly applied to some psychologists whose formative years spanned the early 1920s to late 1940s, it is not accurate to do the same with Cattell. First, he was a product of the times, and many of those with similar beliefs and attitudes (e.g., C. C. Brigham, Lewis Terman, H. H. Goddard) eventually recanted those beliefs formally in the face of better science, a mature perspective of life, or an intolerance for the ruse that drives various aspects of scientifically based racism. In fact, Cattell not only threw over many of the positions which had become socially undesirable and untenable, he actually departed in a significant way from the very idea used to support such discriminatory policies—the belief that there was one and only one type of intelligence (i.e., general intelligence or *g*) and that it was supreme among all other so-called second-order factors that might be identified. That Cattell was able to break with what is the most important empirical foundation for scientifically driven racist beliefs not only indicates that he was not afraid to relinquish such inequitable ideas as fallacious but that he was also willing to challenge the very core of the prevailing statistical ideology that he had been taught by none other than Spearman himself.

Cattell's application of factor analytic techniques and his early dissatisfaction with the idea of general intelligence or a single *g* began with a very brief presentation at the APA annual conference in 1941 published in the *Psychological Bulletin* that may well have been prompted by the renewed interest in the testing of military recruits as the USA entered World War II. In that paper (Cattell 1941), he stated, "the notion of a general factor does not recommend itself so strongly in adult testing because adult tests are less saturated with a general factor" (p. 592). Two things are noteworthy in his comments. First, that he is beginning to see that *g* is an inadequate explanation for intelligence at the adult level. And second, that intelligence must be viewed as a developmental process. Perhaps one of the greatest and most overlooked contributions to intelligence provided by Cattell (and still reflected in research conducted on CHC theory today) is the attention to the manner in which abilities develop, peak, maintain, or decline across the life span. Cattell concerned himself with developmental issues to an extent that is extremely uncommon even today but which is fundamental to any definition. Cattell's movement away from *g* can also be seen in his admonition that answers to the inadequacies of *g* in adults may rest with the work of Thurstone and Thomson, and he offered a practical solution that forms the very beginnings of what would become known as Gf-Gc theory (one of the precursors to CHC theory). His proposed solution to measurement is better delineated in a later publication (Cattell 1943) where he begins to attack tests on several fronts including inadequate psychometric properties, norm samples lacking representation for the general population, and overreliance on manual dexterity. For the most part, however, he decries the paucity of suitable tests for use in evaluating adults, particularly those over the age of 20, and despite listing some 44 popular tests currently in print, Cattell (1943) denounces the lot as reflecting a "dearth of tests" that "must come as a shock to most psychologists, for it has been widely assumed that the momentum of real progress in intelligence test theory and practice which arose in the first two decades of this century as continued unabated through the ensuing 20 years" (p. 156). That tests have failed to demonstrate any useful progress over the prior two decades is ascribed by Cattell to problems with the fundamental theory of intelligence.

At this point in his career, Cattell had already begun dismissing many of the foundations of the genetic arguments for intelligence that had gone hand in hand with Spearman's *g*. Cattell's focus on adults sensitized him to the problems involved in evaluating intelligence free from the effects of schooling, verbal skills, and mathematical abilities and the need to account for the decline in "speed" but not "power" of intelligence as one ages. Cattell was clearly dissatisfied with notions regarding tests of intelligence and their concomitant lack of theory apart from the three basic rules taken from three different fields of study. Clinical study of individuals with low intelligence provided the notion that intelligence involved the capacity to think abstractly. Animal studies and analogs offered up the idea that intelligence was reflected by an ability to learn. And last, measurement in education generated the premise that intelligence must involve the capacity to adapt means to ends. These three principles were reiterated widely at the time and troubled Cattell greatly as evidenced by his citation of Wechsler (1939) and Wells (1932) to wit: "Wechsler, in his Bellevue Scale manual, defines adult intelligence as 'the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment.' But Wells (p. 265), deploring the fact that Wechsler's concept of intelligence involves adding up the subtest scores into a single total, says: 'The chief use of global scores is administrative.'" (p. 159). Cattell argued forcefully that despite a wide array of published tests of intelligence, few authors attempted to provide positive statements about the nature of intelligence, and those that did were no different than what had been offered even 40 years prior. It was not so much that Cattell simply felt any general theory of intelligence was lacking but more that there was very little support for intelligence irrespective of the theory. He notes that "those applied psychologists who have been the most prolific designers and users of 'intelligence tests' and who have so long and so uncritically accepted the sum of a hodgepodge of tests in the form of a single IQ measurement are now swinging—on no better evidence—to the opposite extreme of demanding that tests should yield measurements of separate abilities" (p. 161). All this is not to say that Cattell was completely disenchanted with the notion of a general factor of intelligence. In discussing his opinions regarding the competing viewpoints of Spearman and Thurstone, Cattell argues that Spearman did admit to finding certain group factors and that Thurstone also conceded that a general factor could be identified. But he leans in favor of Spearman by noting that he "introduces his group factors to the reader with a cold and perfunctory politeness, while Thurstone's general factor is only permitted to enter society as a 'second-order factor' after the 'primary abilities' have made off with all of the actual test variance" (p. 170). Still, Cattell emphasizes that factor analysis will not bring such a debate to an end but that it will permit significantly greater objectivity to the entire enterprise. He understood that disagreements in science will continue to stem from differences in how data are viewed and interpreted, but the arbitrariness of the endeavor is removed and elevates the enterprise to the level that true science demands. Graphical representations of Spearman's and Thurstone's models are provided in Fig. 15.1 for comparative purposes.

Following his own admonitions and concerns about theory, Cattell introduced the notion that deterioration in intelligence in adults was not uniform across all tests but differential, with the higher *g*-saturated tests (e.g., vocabulary, information, verbal comprehension) showing the least decline across the life span and relatively *g*-unsaturated tests (e.g., speeded tasks, abstract problem-solving, unfamiliar performances) showing the most precipitous declines. It must have dawned on him quickly that if there is such a thing as a single general factor, the evidence of abilities that decline or do not decline did not support it. A new conceptualization must be created to explain this phenomenon, and on page 178, he finally writes, for perhaps the first time in formal discourse, that the difference between such abilities can be expressed by the terms "crystallized" when implicating the former and as "fluid" in referring to the latter (Cattell 1943). In describing his "hypothesis of fluid and crystallized ability," (p. 180), Cattell postulates that if sustained, his formulation would be critical to intelligence testing in adults by requiring the specific measurement of both abilities rather than relying on notions of general intelligence. It should be understood as well that Cattell was not wholly dismissing Spearman's *g* or attempting to devalue it and its utility. Rather, he was merely breaking it into two relatively equal pieces—both of which could be considered equivalent components to intelligence that should be viewed as distinct, yet cohesive in a general sense. That he likely hoped to retain ties to his mentor, Spearman, is evident in the data and analyses Cattell uses to support his new theoretical formulation. Cattell took great pains to tease out speed issues, noting that there were various aspects of speed which were related to the decline in fluid abilities. Yet, he did not attempt to incorporate speed as a factor in its own right, either because his analysis of the data did not permit it or he could not reconcile the problems a third factor introduces with respect to the idea that there should be only a single general one. Two parts of the same thing was likely acceptable in principle, and Cattell even used Spearman's designations (i.e., lower case *g*f and *g*c) to maintain the link to a single *g*. But three would likely have proven too much of an anomaly, and the matter remained unaddressed until he mentored a dissertation designed to examine his theory by his student John Horn who had no qualms about identifying the presence of additional factors that had been either conveniently overlooked by Cattell or simply hidden by his own personal and professional biases.

Despite his stated concerns about the glacial pace at which intelligence theory had proceeded

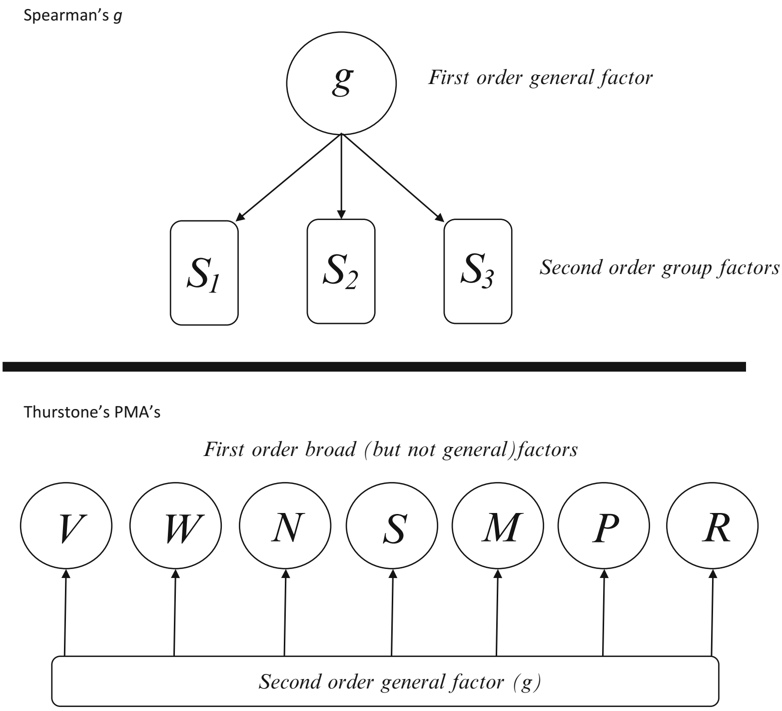

Fig. 15.1 Comparison of Spearman's *g* and Thurstone's primary mental abilities

prior to his explication of a two factor *gf*-*gc* model, Cattell himself allowed two decades of his own to pass before he put his theoretical framework to the test. It was not that he completely neglected the theory, and indeed he offered a few refinements along the way (Cattell 1950; Cattell 1957a, b). But evidence in support of his theory lagged significantly, and Cattell admitted that the bridging of the theory-practice gap was not as simple as it might seem. Part of the problem was likely the industrialization of intelligence tests and testing which had provided an economic boom in its own right and resulted in greater difficulties as well as added costs required for development. Nevertheless, Cattell persisted and after 20 years of theory, he turned his attention to empirical investigation in support of his yet unsubstantiated model. The result was a publication that serves as the official pronouncement of the birth of the "theory of fluid and crystallized intelligence" and outlined a well-developed and modern conceptualization of intelligence that contrasted starkly against the various theoretical frameworks, primarily single *g*, that had been carried over unchanged for the past half century (Cattell 1963). In hindsight, Cattell's inability, reluctance, or other reason for avoiding the necessary research may have also played a role in why his theoretical model was not readily adopted by the major test publishing companies and why, despite the advancements in thinking it accorded, was not used as a platform for the development or revision of current and future intelligence tests. The work of Cattell's student, John Horn, would begin to correct this oversight but not without another three decades of relative obscurity.

CHC Theory and Horn: Headlong into Adolescence

In his landmark paper on *gf*-*gc* theory, Cattell (1963) makes a notable reference to the unpublished work of John Horn, the second major contributor to CHC theory. Cattell emphasized that investigations of *gf-gc* theory cannot be made piecemeal or relative to one ability but not the other. He gleefully noted that "the necessary experimental conditions for constructive conclusions [about the theory] are possible only if the total theory is kept in focus, as is happily the case in, for example, the recent work of Horn" (p. 2). Cattell does not cite Horn's research in the bibliography, but the timing of the article suggests that he was most likely referring to Horn's (1965) dissertation which was in progress around that time. During an informal collegial dinner and discussion among a number of so-called CHC enthusiasts, Horn related personal details on the history of his dissertation explaining that he had hoped to do something quite different, and when it did not work out, Cattell provided him with some data and recommended that he analyze it (J. Horn—personal communication, March 1, 2007). He did, and not surprisingly, the title of his thesis is quite on point, "Fluid and crystallized intelligence: A factor analytic study of the structure among primary mental abilities" and indicates that just as Spearman had passed on the legacy of factor analysis to Cattell, so too did Cattell pass on his affinity for factor analysis to Horn, but not necessarily their attachment to a single *g* or to two related *g* factors (*gf-gc*).

Horn apparently got a very quick start in his role as a contributor to Cattell's newly formed *gf-gc* theory. He had already been studying with Cattell and contributing some research in line with the theory when his dissertation provided a powerful and comprehensive test of the theory, much like Cattell had done in 1963, and inadvertent as his topic may have been, it set the course for much of the rest of his academic career. What Horn found, however, was that Cattell was essentially "wrong" in suggesting that there existed two distinct but similar aspects of general intelligence because his new analyses, completed in the manner specified and approved by Cattell himself, provided support for at least four such primary factors. In addition to what he referred to as "Gf" and "Gc," Horn suggested the data he collected also supported two other primary mental abilities including general visualization (or Gv) and general speediness (or Gs).[1]

Figure 15.2 provides a side-by-side view of Cattell's original *gf-gc* formulation and the modifications and conceptual differences suggested by Horn (1965). As is evident in the illustration, Horn retained the basic definitions provided originally by Cattell in terms of Gf and Gc, including the use of the term "intelligence" as part of the name for each one (i.e., fluid intelligence and crystallized intelligence). He viewed these as broad dimensions exhibited as individual differences involving various aspects of reasoning and problem-solving in both, but without any requirement of pre-training, knowledge, or education in the former and as specifically reflected as necessary "skills which constitute the collective intelligence of the culture and which are learned under conditions of intensive acculturation" (p. 309). The construction of Gc in this manner highlights an important dilemma in test construction that seeks to base itself on sound theory. If an ability is defined as "acculturation" and specified to be the "result … of opportunity such as is occasioned by special schooling and continued exposure to the culture in again," the practice of stratifying normative samples primarily on the basis of age becomes problematic. Certainly, education can be easily controlled as it is not difficult to ascertain the extent to which an individual has received formal instruction over the life span. But rarely is that information coupled with actual age in determining an appropriate standard for comparison. More troubling, however, is the lack of attention paid to the process of cultural knowledge acquisition outside of school that Horn points out as being related to age.

[1] It should be noted here that it is not clear why Horn chose to use capital letters in designating these abilities. Whereas it was not an uncommon practice in the literature at the time, it may have been a deliberate choice on Horn's part so as to reflect his desire to eliminate all direct links to any of the abilities being misconstrued as components of a larger general factor, or g—an idea he was beginning to accept as untenable even in his dissertation. Whatever the case, the capital letter designations have become the default and preferred format within CHC theory and are used throughout the remainder of the chapter.

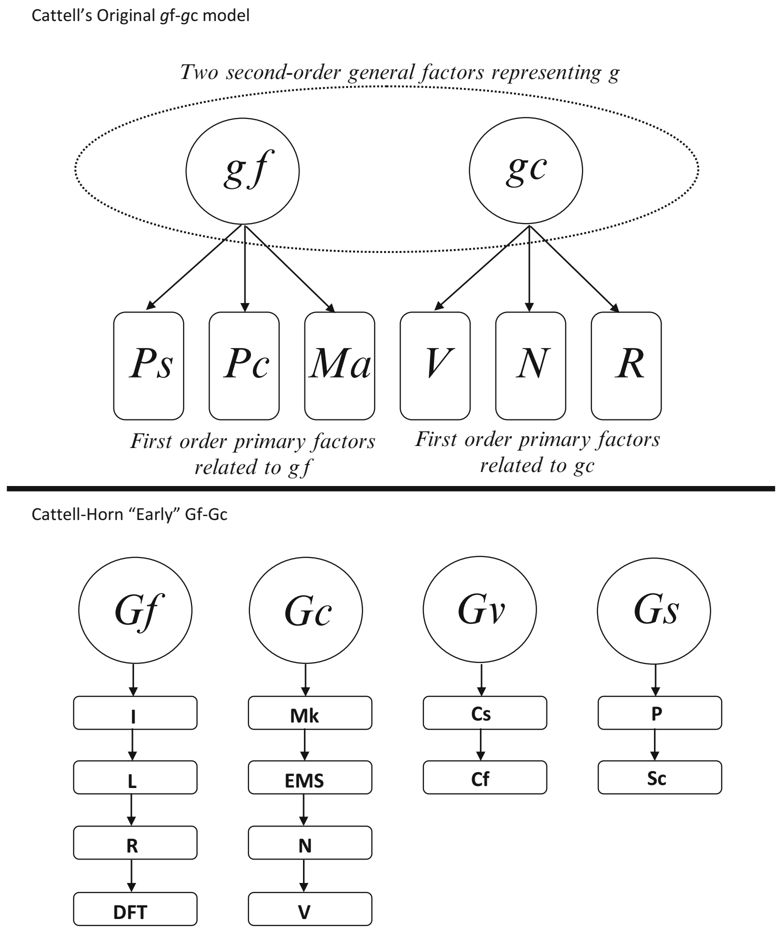

Fig. 15.2 Comparison of Cattell's *gf*-*gc* theory and the Cattell-Horn early Gf-Gc theory

Whereas individuals residing in the same country under relatively similar conditions would be expected to share approximately the same opportunities for learning about the culture in which they live, the same cannot be said for individuals whose opportunities for learning have been limited in comparison to same age peers due to factors such as immigration, ethnic and cultural differences in the home and community, and language differences. Moreover, in what manner can Gc be measured without the use of Gc-based stimuli? As Cattell so proudly announced, the theory of fluid and crystallized abilities must be evaluated as a whole such that evaluation of one or the other alone undermined empirical efforts to support it. This had already been seen in the results of so-called "culture-fair" and "culture-free" tests of intelligence which were intentionally designed to minimize the effects of prior schooling or the need for previous learning but showed only modest correlations to more comprehensive tests and lower *g*-saturation on the whole (Cattell 1943, 1963; Horn 1965). If Gc must be measured given its centrality to the concept of intelligence, a more precise delineation of experiential differences in exposure and prior learning, above and beyond age and education, will be crucial to the generation of fair and equitable standards.

Horn's (1965) analyses presented evidence in support of a general visualization (Gv) primary factor that he described as "the processes of imagining the way objects may change as they move in space, maintaining orientation with respect to objects in space, keeping configurations in mind, finding the Gestalt among disparate parts in a visual field and maintaining a flexibility concerning other possible structurings of elements in space" (p. 310). Cattell had alluded to elements of so-called visual processing in his prior analyses but had mostly seen the issue as one related to the covariance observed in age-related decline of visual perceptual tasks due to degradation of visual acuity. As a developmental psychologist, Cattell understood and recognized the role that diminished vision played in attenuating test performances that relied on visual-perceptual processes, and thus he was inclined not to see it as an independent and distinct factor in its own right. Horn had no such difficulty and in his own elaborate style provided a strong argument for Gv including "quite definite support for the hypothesis of a general visualization dimension spanning the facets of Vz [visualization], S [spatial orientation], Cf [flexibility closure], Cs [speed closure], and DFT [adaptive flexibility] and dipping into measures of Gf when these involve Figural content" (pp. 280–281).

Horn (1965) presented similarly persuasive evidence in support of general speediness (Gs) as a primary factor. He hypothesized that Gs "could perhaps be an attribute indicating a state of test-taking effortfulness, rather than a stable trait" and subject to variation as a function of the nature of a given task (p. 310). Nonetheless, he indicated that Gs "is measured most purely in simple writing and checking tasks which require little in the way of complex relation-perceiving" and further admonished that "the function itself produces variance in the measure of most intellectual functions unless care is taken to cancel it out by measuring with both unspeeded and speeded tasks" (p. 310). Elements of this speed factor included Sc (speed copying), Wf (writing flexibility), and P (perceptual speed).

In a manner of speaking, Horn (1965) simply opened the floodgates with respect to the identification of primary factors, and as Cattell joined him in publication, the affirmation of the empirical support for an early Cattell-Horn Gf-Gc model was solidified (Horn and Cattell 1966a, b). As noted previously, it is a testament to Cattell's ability to alter his beliefs in the face of compelling evidence as it is clear that he was more than happy to let go once and for all the notion that there existed a general intelligence, whether comprised of a single *g* or two *g*'s (i.e., *g*f-*g*c). His outright rejection of this theoretical notion is given special credence by its conspicuous and prominent placement as the very first sentence ever published jointly between he and Horn (Horn and Cattell 1966a) which stated rather emphatically, "the theory of fluid and crystallized intelligence … seriously questions the notion that there is a unitary structure which can be designated general intelligence" (p. 253). Not content with upsetting the proverbial apple cart with this single premise, they add that Gf-Gc theory also "questions the belief—often implicit, but expressed clearly in a recent article by McNemar (1964)—that the conglomerate measured by combining subscores from a collection of intellectual tests is the best estimate of intelligence" (p. 253). In this regard, Horn and Cattell had become more aligned with Thurstone's (1946) original position that:

> Instead of attempting to describe each individual's mental endowment by a single index such as a mental age or an intelligence quotient, it is preferable to describe him in terms of a profile of all the primary factors which are known to be significant…. If anyone insists on having a single index such as an I.Q., it can be obtained by taking an average of all the known abilities. But such an index tends so to blur the description of each man that his mental assets and limitations are buried in the single index. (p. 110)[2]

[2] As yet another example regarding the influence of academic genealogy, Horn co-mentored this chapter's author's own dissertation which examined various methods of data aggregation in defining latent variables—that is, what is the best way to put two or more scores together mathematically to represent a single psychological construct. Prior to the final results, Horn predicted that a simple arithmetic average would emerge as the superior method, and in contrast to the manner in which many constructs and test score composites/clusters are calculated in the present day, he was indeed correct every bit as much as was Thurstone.

Neither Horn nor Cattell was alone in the rejection of a general factor. But for Cattell, whose life, education, and experiences were rooted in just such a notion, it must have been a truly radical departure from his early foundations. On the other hand, Horn was well acquainted with the "British" school and its ideology, having learned it firsthand from both Cattell and via his Fulbright work in Australia (1956–1957) and his position as a research associate at the University of London in 1972. Indeed, having "seen" the other side may have allowed Horn to view the British perspective from a more objective angle and therefore sensitized him to its shortcomings and allowed him to see problems and anomalies where others saw none. His insight into the problems with a general factor was revealed in an interesting manner more recently when he responded to a seemingly innocuous post on the first list serve ever created specifically dedicated to the topic of CHC theory by Kevin McGrew. Not long after its launch, a question arose regarding why the WJ-R (Woodcock and Johnson 1989) seemed to correlate so poorly with the venerable Wechsler scales and whether such modest correlations were indicative of a test that did not actually measure intelligence, particularly in the broad or general sense. Being a charter member of the list serve, Horn took the opportunity to address the issue—which at the time must have seemed that we had all returned to a state of quiet acquiescence of Spearman's *g*. Because these are his words (previously unpublished in their entirety), they merit inclusion in this chapter at this very point and are offered here for the benefit of the reader. His remarks, as they appear below, are quoted in their entirety, exactly as he wrote them on August 2, 1999.

> The problem is that there is no g--.e., no single g. Of course this is contrary to existing dogma. But dogma is dogma, not evidence, not something we want much of in science. It is an assumption implicitly accepted, an assertion made so frequently, by so many who are assumed to be (and assume themselves to be) authorities, and made so uncritically that it is widely accepted as true. (How could something said so often, so confidently, so casually, by so many, and so many smart, and informed people, not be true?) But the evidence adds up, as I have said now so many, many times –ad nauseam some may think. Still, for those who care about evidence, there is lots of it. One can examine it, and when one does one finds a drip, drip, drip of results from study after study punching out huge holes in the belief that there is a g (somewhere) and demonstrating that g hasn't been found and that it now seems unlikely that it will be found. In any case, if there is a g, we have yet to find it.
>
> And there is no contrary evidence, no evidence supportive of g. The only thing that gets treated as evidence is positive manifold of the intercorrelations among measures of cognitive abilities and a string of correlations with other variables that reflect this positive manifold. But this is evidence that Thurstone showed many years ago does not support a structural hypothesis of g, much less a developmental, genetic, neurological, educational, social, anthropological--n general, a construct validit--hypothesis.
>
> Recently, for example, McArdle has presented no fewer than three studies showing that g does not work structurally, developmentally, and dynamically. Also recently is the evidence of Richard Roberts analyses of the Armed Services Vocational Aptitude Battery (ASVAB)--he battery used in the data analysis parts of the infamous Herrnstein & Murray "Bell Curve" study. In the H&M studies obeisance was given to g when in fact the evidence of H&M's own factoring indicated no g. Roberts' results elegantly demonstrate this. (Here one might want to look at my review of H&M's book, there also pointing out this problem. Also good reading on this point are the Haut et al. reports, book and papers).
>
> Just a couple of years back, Schonemann and a whole host of responders to his work, concluded that there is no g. A little further back in history is Carroll's monumental work where, as I point out in several papers (again ad nauseum perhaps), there are no fewer than 8 different general factors, all quite distinct, but still referred to as "the" (singular) general factor or g. Prior to that, reviewing Jensen's "Bias in Mental Testing," Horn & Goldsmith found that what Jensen referred to as "g" in one chapter of his book was most similar to Gc, what he referred to as g in another chapter was similar to Gf and what he accepted as g in still another chapter was essentially Gv. While Jensen's work presents particularly stark examples of this chameleon-like interpretation of ability measurements, in fact he is simply doing what many others do. But if one looks at the evidence, s/he will see Gf, Gc, Gv, etc., have quite distinct construct validities –quite different relationships to neurological, educational, vocational, genetic variables--n general the network of variables that provide a basis for understanding human capabilities. Going back further yet there are the classic studies of El Koussy (1935) and Rimoldi (1948) studies that

were steadfastly and beautifully designed to prove the validity of g, but concluding--eluctantly, almost sadl--that the g hypothesis can not be supported. Then, too, more tangentially, there are the well-designed and well-executed studies of Gustafsson (1984, 85), Undheim (1976) and Undheim and Gustafsson (1987) showing that in batteries of tests designed for children the general factor was identical to the Gf factor. Relatedly, there are the results from our work showing that a battery very carefully designed to provide evidence of one and only one factor corresponding to Spearman's g comes very close to succeeding, as in Thurstone and Thurstone (1941), but the g that is indicated is Gf (and only Gf): as soon as other well-regarded indicators of intelligence, such as those of Gc, Gv, Ga, etc., are considered, that "g" factor (which is Gf) disappears.

So, old friends of NASP--and Jensen, Bouchard, Eysenck, Carroll, etc. (the list is long) be aware that no battery of ability tests provides a measure of g, because there is no g, only conglomerate, composites. One good reason why the composite score on the WJR may correlate at a lower level with this or that composite or other variable is because the WJR is well designed to provide measures of the different concepts of human cognitive capabilities--hat in the vernacular is referred to as intelligenc--that, so far, have been indicated by research. It provides measures of Gv, Ga, Gs, SAR, TSR, Gq, as well as Gf and Gc, whereas the Wechsler scales provide only Gc, a Gf-Gv mixture, and a very weak SAR and Gs. The composite of the WJR is thus a broad mixture relative to the composites of other, more narrow, batteries. But even when the same elements of a composite appears in other batteries, the elements enter in different proportions to the whole: the composites of different published tests differ not only in breadth, but also in the proportions of different abilities that contribute to the composite measure. A broad composite relative to a narrow one needn't necessarily correlate at a lower (or higher) level with other variables, but it may. It depends on breadth of the variable with which the composites are correlated and on how well the components of a predictor composite match the components of the predicted variable. In prediction of job performance on many jobs, for example, as in much of the research reviewed by Schmidt and Hunter (1992), the broad composite of the ASVAB (and it's descendents) predicts better than most narrower composites.

Enough said. These points are not highly debatable. One can have a quibble here and there, but basically the evidence at this point in history doesn't permit much deviation from the conclusion that there is no g; the emperor is naked.

Sincerely,
John Horn

Of primary significance in Horn's comments is the argument that attempts to distill measurement of a single general ability factor result only in the measurement of a distinct broad ability factor, notably Gf, when language and cultural elements are not used, or Gc, when they are. Horn also makes reference to the version of the theory that became known as the "modern Gf-Gc" framework and which greatly expanded the number of primary (narrow) and secondary (or broad, but not general) mental abilities included in the theory. That expansion was relatively rapid paced as in (1966a), only a year after introducing two new broad, secondary factors in his dissertation (Gv and Gs), he adds a fifth to the collection "F" (general fluency) which was more of a process that was reflected in certain tasks, particularly those that required speed. The specific abilities subsumed under this broad factor included Fa (associated fluency), Fi (ideational fluency), and Fw (word fluency). By the early 1990s, Horn had expanded the broad abilities which now numbered ten in all and included as many as 80 or so primary (narrow) abilities subsumed by them collectively. The usual suspects remained, Gf, Gc, Gv, and Gs, but F had become TSR (fluency of retrieval from long-term storage), and another memory component had been identified, SAR (short-term apprehension and retrieval). In addition, three new broad abilities were incorporated, one very similar to Gv but relying on auditory stimuli and perception, Ga (auditory processing); one very similar to Gf and Gc, but specific to mathematical or quantitative knowledge (Gq); and one very similar to speed (Gs) but labeled correct decision speed (CDS) to indicate rapidity in providing correct, not merely quick, responses in relatively simple comprehension, reasoning, or problem-solving tasks. A final factor related to reading and writing skills, Grw, was also added as it became more commonplace to include published tests of academic achievement right alongside cognitive ability tests (a distinction that Horn indicated was only a semantic issue and not a true difference). As Horn continued to advance the theory, it began to be referred to as "modern" Gf-Gc theory and later as "extended" Gf-Gc theory.

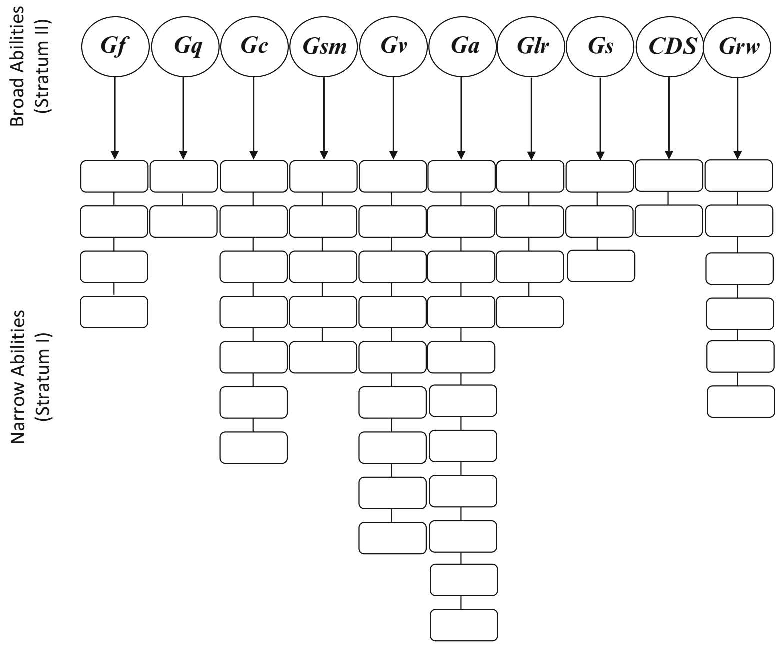

Fig. 15.3 The Cattell-Horn "extended" Gf-Gc model

Regardless of the name, a general factor supreme to all other broad and narrow abilities was, of course, absent in each refinement of the Gf-Gc model. Figure 15.3 provides an illustration of the extended Gf-Gc model delineated by Horn late in his career (Horn and Blankson 2007; Horn and Noll 1997).

Around 1988, having a rather a theoretical test of intelligence under his belt already (i.e., Woodcock-Johnson Psycho-Educational Battery; Woodcock and Johnson 1977), Richard Woodcock journeyed to the University of Southern California likely in search of better theoretical guidance. His collaboration with Horn resulted in not only the first published test specifically designed to operationalize modern Gf-Gc theory, it also prompted the publication of an often overlooked and important article that further established the validity and utility of the theory, particularly as a platform for test development (Woodcock 1990) that not only affirmed the empirical support for modern Gf-Gc theory across a variety of published instruments, but also reintroduced a concept that had long since vanished—that "the clinician may find it helpful to 'cross' batteries to obtain a set of measurements required for a particular assessment" (p. 252). Coupled with his three prior points on appropriate psychometric principles that must govern test data (i.e., knowledge of the factorial composition of each subtest in a battery, formation of broad ability composite or cluster scores drawn from two similar but qualitatively distinct narrow ability indicators, and avoidance of subtests with mixed-factor loading that complicate, if not obviate, explanations of test performance), the foundations of what would become CHC cross-battery assessment (McGrew and Flanagan 1998; Flanagan and Ortiz 2001; Flanagan et al. 2007, 2013) are evident. Ironically, the suggestion that batteries could be "crossed" was not a new idea. Cattell (1943) himself, commenting on the vast number of published intelligence batteries generated over the preceding 20 years, noted that "it is at first glance a sufficiently impressive window display; indeed, the adult-testing psychometrist may be led to consider himself richly equipped with 44 tests" (p. 154). Using a variety of tests culled from a range of individual batteries was relatively commonplace and even necessary precisely because they lacked any real theoretical foundation. According to Atwell et al. (1941), "the verbal items of the Wechsler-Bellevue Intelligence Scale, supplemented by a vocabulary test and alternate arithmetic questions from the Alpha test would be satisfactory … it was expected that the Beta Block Counting test, the 11, 12, and 14 year levels of the Porteus mazes, and the third, fourth, and sixth designs of the Wechsler-Bellevue Block Design test would be relatively useful" (p. 898). Both Cattell's and Horn's analyses in support of the theory of fluid and crystallized intelligence relied on test data generated across a range of tests and batteries. For unknown reasons, however, clinical practice with testing had settled largely into a test-kit-driven modality where, apart from some of the practices of neuropsychologists, intelligence was measured and determined almost exclusively by the structure of a single test—a practice fraught with peril, as Cattell, Horn, and Woodcock all noted, because it meant that the resulting intelligence was not equivalent to the prevailing conceptualization of intelligence but rather "an average of whatever has been chosen by the test author to be included in that battery" (p. 250). Whereas the field in general might have lost sight of this principle, cautions remained regarding the inappropriate use of IQ and inaccurate perceptions of the construct as eloquently stated by Salvia and Ysseldyke, "different intelligence tests are simply samples of behaviors. For that reason it is wrong to speak of a person's IQ. Instead, we can refer only to a person's IQ on a specific test … Because the behavior samples are different for different tests, one must always ask, 'IQ on what test?.'" (p. 158). Such wisdom has gone unheeded too long in applied psychology, but the popularity and rise of CHC theory and the relatively quick mustering by test developers in aligning themselves with current intelligence theory have reawakened an interest in understanding this important idea while at the same time helping to de-emphasize the utility and value of global intellectual scores.

CHC Theory and Carroll: Coming of Age

Adolescence is often a period of time where concerns about self-identity become salient. And as the Cattell-Horn modern Gf-Gc theoretical framework matured, an important event occurred that provided an additional foundation regarding the evolution of CHC theory into a form more closely resembling its present incarnation. That event was the publication of John Carroll's (1993) remarkable book *Human Cognitive Abilities: A Survey of Factor-Analytic Studies*. In short, Carroll undertook examination of over 50 years worth of data drawn from tests of intelligence and cognitive abilities to create a single, massive database with which he could perform his own factor analyses. Carroll was insistent upon the use of exploratory rather than confirmatory techniques because he wished to allow the "data to speak for themselves." Whether he went in with any preconceptions about the structure of intelligence or not is unknown, although his eventual insistence and firm arguments in favor of a general factor may offer some insight into his a priori beliefs. Nevertheless, Carroll distilled some 2,000 available datasets published between 1983 and 1985 (approximately) down to about 460 which he believed met critical criteria necessary to permit his analyses and required for the sake of eliminating data that were less than trustworthy on various psychometric and theoretical grounds. This included datasets that contained a substantial number of variables, a sizable sample (greater than 100), a published correlation or covariance matrix, and sufficient descriptions of the sample and variables to permit interpretation (Carroll 1997).

Carroll drew from Cattell (1971) in his use of the term "stratum" to describe the difference between first-, second-, and third-order factors. Because different datasets may contain information that only permits construction of only a first- and second-order factor, there had been some confusion about whether a general factor was indicated at the second level or at the third.

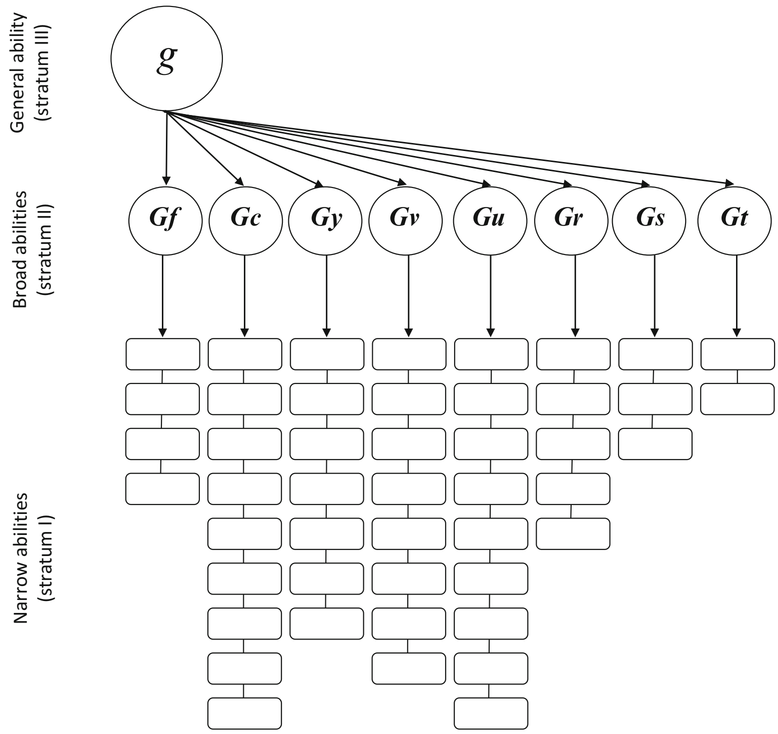

Fig. 15.4 Carroll's three-stratum model

Carroll sought to minimize such confusion by implementing Cattell's stratum notion in ways that clearly delineated the nature of the ability or factor identified at each of the three levels. Thus, Carroll (1997) named the "first-order factors resulting from analysis of typical sets of psychological datasets *factors at the first stratum,* or *stratum I factors*" (p. 124; emphasis in original). Likewise, "*stratum II factors* were second-order factors from such data sets, and *stratum III factors* were third-order factors from such datasets" (p. 124) and postulated that any ability must fall at one of these three levels.

Carroll's (1997) ultimate intent was to provide extensions to and expansions of existing theoretical models by providing a "provisional statement about the enumeration, identification, and structuring of the total range of cognitive abilities known or discovered thus far" (p. 124). If taken at face value, Carroll's work provides significant support for modern Gf-Gc theory, above and beyond other conceptualizations of intelligence. Carroll (1993) noted specifically that "the Cattell-Horn model … is a true hierarchical model covering all major domains of intellectual functioning … among available models it appears to offer the most well-founded and reasonable approach to an acceptable theory of the structure of cognitive abilities" (p. 62). Despite this ringing endorsement, Carroll outlined specific areas in which his proposed three-stratum model differed from the Cattell-Horn formulation and other similar theoretical models. In doing so, it may have fostered the impression that he was indeed, despite his reservations, proposing a newer and better model which should, in logical fashion, supplant the less correct extended Gf-Gc framework. Whatever the reason, Carroll's formulation has become known in its own right as the three-stratum model of intelligence. Figure 15.4 provides an illustration of the model that Carroll proposed on the basis of his analyses.

At the narrow ability level, Carroll's (1993) analyses revealed about 65 primary, first-order factors. These are specific tasks measured relatively purely and cleanly by a single task, most often couched as a subtest within a larger battery of tests. The sheer number of abilities at this level precludes inclusion of their names and definitions in their entirety, and the reader is referred to other sources for such information (e.g., Carroll 1997). At the broad ability level, Carroll's (1993) analyses revealed only eight broad abilities—a result that was not surprising since he likely confined himself to intelligence tests. If the nomenclature applied by Carroll is loosely interpreted, the resemblance to modern (or extended) Gf-Gc theory was quite good. For example, the broad abilities of Gf, Gc, Gv, and Gs were equivalent in both definition and labels. The Cattell-Horn model used Ga for auditory processing, whereas Carroll used the designation "Gu." A greater difference was evident in Carroll's use of "Gy" for general memory and learning, in contrast to the Horn-Cattell use of SAR (which began being referred to as Gsm), as well as in the delineation of "Gr" or broad retrieval ability which was called TSR (which also began being referred to as Glr) in the extended Cattell-Horn Gf-Gc model. And finally, Carroll labeled his speed factor "Gt" referring to processing speed and RT (decision speed) as one unified broad factor compared to the Cattell-Horn formulation that split the broad factor into two components: Gs, processing speed, and CDS, correct decision speed.

The most significant and obvious difference in Carroll's three-stratum model and the extended Horn-Cattell Gf-Gc model rests with the concept of a general factor. As already discussed, Cattell had envisioned a general factor comprised of two distinct components, and Horn had dispensed with the notion of a general factor from the outset. Neither saw any rationale nor need for it, and neither factored their data in a way that supported it. For them, it was a mathematical nonnecessity, a statistical artifact, and an illusion that simply was not worth pursuing. Carroll, on the other hand, appeared to care deeply about a general factor. In adopting a three-stratum model vs. a two-stratum model, he made a deliberate choice to create a level in which the general factor could exist. In his diagrams, this third-order factor (which should have less significance than first- or second-order factors) is also intentionally placed at the top providing a clear indication of its superiority within a hierarchical structure. Moreover, it is positioned to the left side right above Gf and Gc, as a way of indicating that those abilities bear the closest relationship to it by virtue of being the most *g*-saturated. Of course, one could argue, as did Cattell, Horn, Thurstone, and others, that the general factors are simply Gf anyway and a mere duplication of the second-order factor. In 2003, he asserted that "researchers who are concerned with this structure in one way or another…. can be assured that a general factor *g* exists, along with a series of second-order factors that measure broad special abilities" (p. 19). It seems impossible, perhaps even needless, to elaborate more on this debate. It is sufficient to recognize that it is in fact a debate, and not to assume as so many have done erroneously, that *g* is an established scientific fact. Likewise, if one wishes to dispense with *g* altogether, it should only be in service to the purposes of evaluation which neither need nor require it. The peril in this regard is to succumb wholly to one position or the other when the reality is that neither, as of yet, is supported by any incontrovertible evidence that makes either position defensible. If applied psychologists continue to demand *g*, or global, full-scale scores intended to represent general intelligence, then test publishers will no doubt continue to offer it. Whatever the case, it should be recognized that aggregating scores to produce a general index is a simple enterprise, perhaps too simple, and that because it can be so easily constructed, it may prove seductive for use in ways that cannot be supported psychometrically and theoretically.[3]

[3] I once had the opportunity to ask Richard Woodcock why his WJ-R contained a global intellectual ability (GIA) score when the test was operationalized according to extended Gf-Gc theory that did not specify such a general factor. His response was both enlightening and discouraging as he admitted, almost apologetically and reluctantly that he could not have gotten the test published without including it.

CHC Theory and an Integrated Framework: Maturing in Adulthood

Despite the apparent differences between the extended Cattell-Horn Gf-Gc model and Carroll's three-stratum model, as well as the irreconcilable issue of *g* or not to *g*, a rather unusual thing happened in the late 1990s. Whereas it would have been logical to reason that intelligence theorists and their personal frameworks would fracture the landscape to the point that none of them would be suitable for guiding test development, the very opposite occurred, and attempts were made to consolidate and integrate them in one overarching theoretical framework. Why this may have occurred can probably be traced to several factors. For example, neither extended Gf-Gc nor the three-stratum model was well recognized or popular in the mainstream discussions or measurement of intelligence, so not a lot of researchers, let alone practitioners, paid them much attention. In addition, the WJ-R was making strong inroads, however, and beginning to craft out a place of its own among the now relatively small pantheon of comprehensive intelligence tests that had boiled down, more or less, to the Wechsler and Stanford-Binet scales, Kaufman Assessment Battery for Children, and Differential Abilities Scales. Yet it still lagged significantly behind the others, particularly the Wechsler scales in use and acceptance among applied psychologists. As noted previously, Kevin McGrew and Dawn Flanagan adopted the principles set forth by Woodcock (1990) and outlined the foundations of cross-battery assessment (often referred to as XBA; Flanagan and McGrew 1997; McGrew and Flanagan 1998) which placed extended Gf-Gc theory at its core. But perhaps the key circumstance during this period was McGrew's reconciliation and integration of the Cattell-Horn Gf-Gc and Carroll's three-stratum model as a guide to bridging intelligence theory with the practice of intellectual assessment (McGrew 1997). McGrew specifically outlined a "proposed comprehensive Gf-Gc framework" that he generated via joint confirmatory cross-battery factor analyses drawn from subtest data generated by the DAS, K-ABC, KAIT, SBIV, WISC-III, WPPSI-II, WAIS-III, and WJ-R.

Given the similarities of the two models, it would seem that such a task did not present many difficulties, but that would be an incorrect characterization. First, many of the subtests and batteries McGrew included had never been factored in accordance with Gf-Gc theory, as had the WJ-R subtests. Due to the confirmatory nature of the analyses, expert classifications had to be made for many tests to provide a foundation for testing the relations among them. Second, not all batteries measured all broad abilities, and thus, data on some abilities was likely to be rather limited (e.g., only the WJ-R provided measures of auditory processing). But as Cattell had noted, the theory should be tested in its totality, and it would be necessary to ensure that adequate coverage in terms of both breadth of abilities measured as well as depth of abilities existed or else the results might prove rather limited.

McGrew's initial analysis resulted in the extraction of nine broad abilities (one less than Cattell-Horn's and one more than Carroll's) including Gc, Gv, Gq, Grw, Gsm, Gf, Gs, Glr, and Ga. Given the limitations of the tests he used, he was only able to identify about 36 narrow abilities in the dataset. Some, like Gsm, Gf, and Gs, contained only two identified narrow abilities, whereas others like Gc, Gv, and Grw subsumed numerous narrow abilities, seven, six, and seven, respectively. Of particular note is that in many cases (9 out of the 36), only one subtest from one battery was present to provide data for a given narrow ability. This is not so much a limitation of McGrew's study but more an indictment on the narrowness of the factor structures upon which the tests had been developed. Later versions of the model contain ten broad abilities that include Gt (reaction time/decision speed) which subsumes three additional narrow abilities, but it is sometimes omitted since it is not currently measured by any major intelligence battery. In addition, some researchers have called for a separation of Grw into its constituent components, using the designations Grw-R for reading skills and Grw-W for writing skills (Flanagan and Ortiz 2001; Flanagan et al. 2007, 2013). McGrew asserts that these factors do not distinguish themselves in factor analytic studies and tend to be very highly correlated. The association between the two is quite clear as they are both symbolic aspects of language development. But because schooling specifically treats them and teaches them as independent skills, there is a practical advantage in assessment that comes from making this distinction. However, it has not yet been fully incorporated into current CHC theoretical specifications as it presents a condition that cannot be supported empirically.

Once again, it appears that fortuitous events reopened the floodgates regarding development and advancement of the theory. In hindsight, the integrated model was only just beginning to blossom. Consider that in 1985, Horn, Carroll, and McGrew were called upon as consultants regarding the revision of the 1978. Schneider and McGrew (2012) hails this "meeting of the minds" as "a moment where the interests and wisdom of a leading applied test developer (Woodcock), the leading proponent of Cattell-Horn Gf-Gc theory (Horn), and one of the preeminent educational psychologists and scholars of the factor analysis of human abilities (Carroll) intersected" came into a perfect alignment of psychometric stars that served, in his opinion, as "the flash point that resulted in all subsequent theory-to-practice bridging events leading to today's CHC theory and related assessment developments" (p. 144). Following his later integration, McGrew teamed with Woodcock and Nancy Mather in 1999 to develop and subsequently publish the Woodcock-Johnson III (Woodcock et al. 2001). By this time, the integrated model had taken on a new name that McGrew cites as having first been presented in the WJ-R III technical manual (McGrew and Woodcock 2001) where the full name "Cattell-Horn-Carroll theory of cognitive abilities" appears and is described as "an amalgamation of two similar theories about the content and structure of human cognitive abilities" (p. 9). McGrew further notes that by amalgamation, and by implication, the name was partially derived from personal communication with both Horn and Carroll in 1999 and that they had recommended the name and that it be structured according to order of contribution.

And so was born CHC theory, which by this point continued to provide the long sought-after common taxonomy of abilities and nomenclature that permitted further advancement by ensuring that all researchers and all studies were finally talking about the same things. What was Gf in one study or on one test was now comparable and relatively equivalent to Gf in another study or another test. It is no small point to say that the viability and success and ever growing popularity of CHC theory is rooted largely in the fact that it has created a landscape that has enhanced theoretical and psychometric development by clearly delineating factors, tests that measure those factors, tests that do not measure them, and language common to all that reduces confusion and ambiguity. McGrew referred to Carroll's work, upon which much of the nomenclature of the integrated CHC model is based, as the "Rosetta stone" of the field of intelligence. With an extensive history of development and increasingly widespread use in current research and development, the momentum of CHC theory is such that it may sweep up many other lesser models in its wake. This fact has not gone unnoticed by test publishers either in that the first decade of the twenty-first century saw a rapid convergence on CHC theory or radical revisions to the factorial structure of tests and their subtests to the point that it was described, albeit facetiously, as a miraculous and "sudden collective psychometric epiphany" (Flanagan et al. 2007, p. 221).

Without question, CHC theory has had a significant impact in terms of promoting theoretical developments in the area of intelligence and cognitive abilities going on nearly a full century now. And despite getting an extremely late start with respect to influencing the design and structure of tests used in measuring human cognitive abilities, it has made impressive gains in just the last two decades and shows little sign of slowing down any time soon. Figure 15.5 provides an

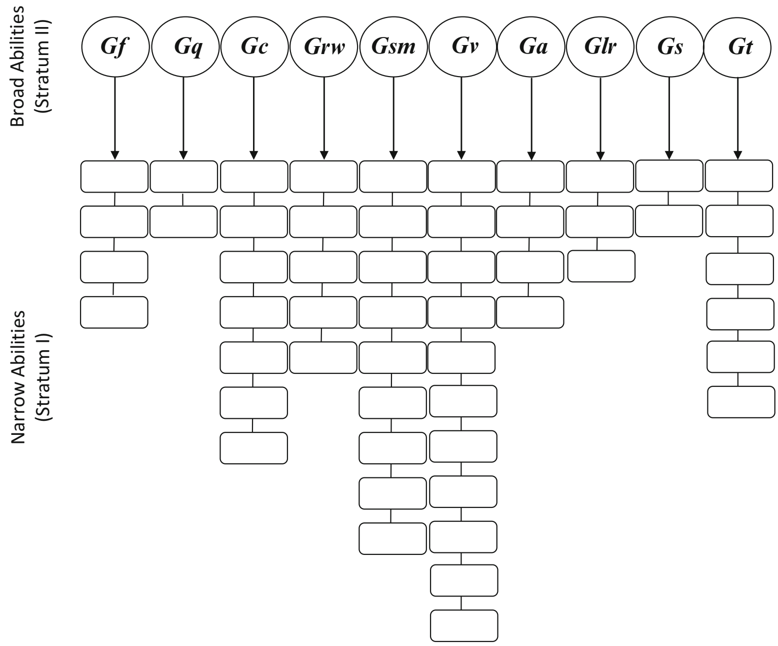

Fig. 15.5 CHC theory "early" integrated model

illustration of the "early" integrated CHC model as formulated by McGrew (1997).

CHC Theory—Aging Gracefully, A Summary of Sorts

With incredible modesty and recognition of the absolute purity of the scientific process, note with all due sincerity that "the extended theory of fluid and crystallized (Gf and Gc) cognitive abilities is wrong, of course, even though it may be the best account we current have of the organization and development of abilities thought to be indicative of human intelligence" (p. 41). They further assert that "all scientific theory is wrong. It is the job of science to improve theory. That requires identifying what is wrong with it and find out how to change it to make it more nearly correct" (p. 41). It is unlikely that the CHC theory will ever be modified to the point that it becomes completely correct, and it may well be overthrown by a better and more accurate theory at some point in the future. CHC theory offers just one view of the nature and specifics of human cognitive abilities, including intelligence, but it need not be seen as the final word on the matter. Nevertheless, its value as a useful and guiding paradigm is well established and continues to inspire both confidence and interest in what might be accomplished with further refinement. Consider that in the very latest incarnation of CHC theory (Schneider and McGrew 2012), fully 16 broad abilities are now specified along with 81 narrow abilities. In addition to the ten abilities described previously, Schneider and McGrew outline six new ones including Gkn (domain-specific knowledge), Go (olfactory ability), Gh (tactile ability), Gp (psychomotor ability), Gk (kinesthetic ability), and Gps (psychomotor speed). Despite this elegant expansion, none of the aforementioned broad abilities are measured by any current battery which precludes their measurement and

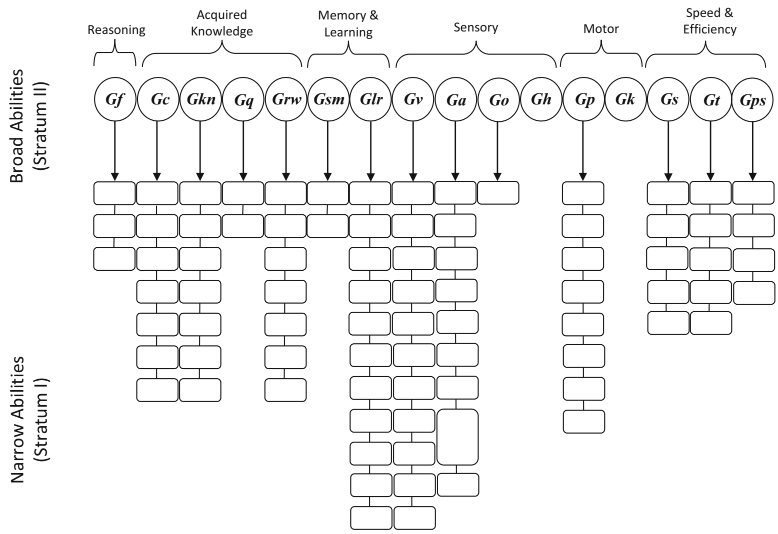

Fig. 15.6 CHC theory "current" integrated model

limits assessment to the ten abilities noted previously. Likewise, of the 81 narrow abilities, only 38 (just two more than before) can be measured and evaluated by current tests. A simplified illustration of this "current" version of the integrated CHC model is presented in Fig. 15.6.

Interestingly, much of the current discussion regarding CHC theory does so without much attention to the notion of general intelligence. There does not appear to be any deliberate attempt to include or exclude *g* in the latest integrated CHC theoretical models, and its relative absence may be more of a reflection regarding interest in broad and narrow abilities and their ability to predict well specific areas of academic skill development above and beyond what is captured solely by *g* (Keith and Reynolds 2010). Because the preceding discussion has made it clear that *g* is neither necessary nor desirable in all cases, and because no test publisher is likely to release a test without including some global score, it will remain an option for any assessor who wishes to use it. Therefore, its inclusion within current theory is not as compelling as it once might have been, especially as research into the narrow abilities continues to demonstrate important and specific relationships between cognitive and academic abilities that are quite useful in psychoeducational evaluations (Schneider and McGrew 2012). While the theory-practice gap that Cattell, Horn, and McGrew intended to bridge via refinements to their theoretical models remains even today, it is now a combination of tests that have not yet caught up to theory coupled with theory that continues to grow and refuses to sit still. In that regard, Cattell, Horn, and Carroll would all likely take heart in knowing that their burning interest in furthering an understanding of intelligence and human cognitive abilities has been passed on intact to the current generation of psychological scientists. CHC theory has grown up, and it would be safe to assume that Cattell, Horn, and Carroll would likely be very proud to know that their goals, their ideas, and their passion are still alive and kicking in CHC theory to the present day.

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Multiple Intelligences in the New Age of Thinking

16

Robert J. Sternberg

In this chapter, I describe two theories that involve the idea of "multiple intelligences." The first is the theory of multiple intelligence (MI theory—Gardner 1983, 1993, 2006). The second is the theory of successful intelligence (Sternberg 1997, 2003, 2005, 2009, 2010).

Multiple Intelligences Theory

Howard Gardner (1983, 1993, 2006) has proposed a theory of multiple intelligences, according to which intelligence comprises multiple independent constructs, not just a single, unitary construct. However, instead of speaking of multiple abilities that together constitute intelligence (e.g., Thurstone 1938), this theory distinguishes eight distinct intelligences that are relatively independent of each other.

The multiple intelligences are linguistic intelligence, used to read, write, speak, and listen to speech; logical-mathematical intelligence, used to solve mathematical and logical problems; spatial intelligence, used to imagine how objects would look if they were rotated or otherwise displaced in space; musical intelligence, used to compose, play, and appreciate music; bodily-kinesthetic intelligence, used to coordinate oneself and to participate successfully in athletics; interpersonal intelligence, used to understand other people; intrapersonal intelligence, used to understand oneself; and naturalist intelligence, used to understand the natural world.

Each intelligence is a separate system of functioning, although these systems can interact to produce what we see as intelligent performance. Looking at Gardner's list of intelligences, you might want to evaluate your own intelligences, perhaps rank ordering your strengths in each.

In some respects, Gardner's theory sounds like a factorial one. It specifies several abilities that are construed to reflect intelligence of some sort. However, Gardner views each ability as a separate intelligence, not just as a part of a single whole. Moreover, a crucial difference between Gardner's theory and factorial ones is in the sources of evidence Gardner used for identifying the eight intelligences. Gardner used converging operations, gathering evidence from multiple sources and types of data.

In particular, the theory uses eight "signs" as criteria for detecting the existence of a discrete kind of intelligence (Gardner 1983, pp. 63–67):

1. Potential isolation by brain damage. The destruction or sparing of a discrete area of the brain (e.g., areas linked to verbal aphasia) may destroy or spare a particular kind of intelligent behavior.

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2. The existence of exceptional individuals (e.g., musical or mathematical prodigies). They demonstrate extraordinary ability (or deficit) in a particular kind of intelligent behavior.
3. An identifiable core operation or set of operations (e.g., detection of relationships among musical tones). It is essential to performance of a particular kind of intelligent behavior.
4. A distinctive developmental history leading from novice to master. It is accompanied by disparate levels of expert performance (i.e., varying degrees of expressing this type of intelligence).
5. A distinctive evolutionary history. Increases in intelligence plausibly may be associated with enhanced adaptation to the environment.
6. Supportive evidence from cognitive-experimental research. An example would be task-specific performance differences across discrete kinds of intelligence (e.g., visuospatial tasks versus verbal tasks). They would need to be accompanied by cross-task performance similarities within discrete kinds of intelligence (e.g., mental rotation of visuospatial imagery and recall memory of visuospatial images).
7. Supportive evidence from psychometric tests indicating discrete intelligences (e.g., differing performance on tests of visuospatial abilities versus on tests of linguistic abilities).
8. Susceptibility to encoding in a symbol system (e.g., language, math, musical notation) or in a culturally devised arena (e.g., dance, athletics, theater, engineering, or surgery as culturally devised expressions of bodily-kinesthetic intelligence).

Gardner does not dismiss entirely the use of psychometric tests. But the base of evidence used by Gardner does not rely on the factor analysis of various psychometric tests alone. In thinking about your own intelligences, how fully integrated do you believe them to be? How much do you perceive each type of intelligence as depending on any of the others?

Gardner's view of the mind is modular. Modularity theorists believe that different abilities—such as Gardner's intelligences—can be isolated as emanating from distinct portions or modules of the brain. Thus, a major task of existing and future research on intelligence is to isolate the portions of the brain responsible for each of the intelligences. Gardner has speculated as to at least some of these locales. But hard evidence for the existence of these separate intelligences has yet to be produced. Furthermore, there is no real evidence for the strict modularity of Gardner's theory. Consider the phenomenon of preserved specific cognitive functioning in autistic savants. Savants are people with severe social and cognitive deficits but with corresponding high ability in a narrow domain. They suggest that such preservation fails as evidence for modular intelligences. The narrow long-term memory and specific aptitudes of savants may not really be intelligent. Thus, there may be reason to question the intelligence of inflexible modules.

I do not detail this theory further because there has been no empirical evidence collected since MI theory was proposed that validates the theory as a whole and the one extensive study that has been done yielded results inconsistent with it (Visser et al. 2006).

The Triarchic Theory of Successful Intelligence

The Nature of Intelligence

There are many definitions of intelligence, although intelligence is typically defined in terms of a person's ability to adapt to the environment and to learn from experience (Inteligence and its Measurement: A Symposium, 1921; Sternberg and Detterman 1986). The definition of intelligence here is somewhat more elaborate and is based on my (Sternberg 1984, 1997, 1998, 1999b, 2000, 2003) theory of successful intelligence. According to this definition, (successful) intelligence is (1) the ability to achieve one's goals in life, given one's sociocultural context; (2) by capitalizing on strengths and correcting or compensating for weaknesses; (3) in order to adapt to, shape, and select environments; (4) through a combination of analytical, creative, and practical abilities. In recent years, I have emphasized that intelligence best serves individuals and societies when it is augmented by wisdom (Sternberg 2003, 2008).

According to the proposed theory of human intelligence and its development (Sternberg 1997, 1999a, 2003, 2004, 2009), a common set of processes underlies all aspects of intelligence. These processes are hypothesized to be universal. For example, although the solutions to problems that are considered intelligent in one culture may be different from the solutions considered to be intelligent in another culture, the need to define problems and translate strategies to solve these problems exists in any culture. Even within cultures, there may be differences in what different groups mean by intelligence (Okagaki and Sternberg 1993; Sternberg 1985b).

Metacomponents, or executive processes, plan what to do, monitor things as they are being done, and evaluate things after they are done. Examples of metacomponents are recognizing the existence of a problem, defining the nature of the problem, deciding on a strategy for solving the problem, monitoring the solution of the problem, and evaluating the solution after the problem is solved.

Performance components execute the instructions of the metacomponents. For example, inference is used to decide how two stimuli are related and application is used to apply what one has inferred (Sternberg 1977). Other examples of performance components are comparison of stimuli, justification of a given response as adequate although not ideal, and actually making the response.

Knowledge-acquisition components are used to learn how to solve problems or simply to acquire declarative knowledge in the first place (Sternberg 1985a). Selective encoding is used to decide what information is relevant in the context of one's learning. Selective comparison is used to bring old information to bear on new problems. And selective combination is used to put together the selectively encoded and compared information into a single and sometimes insightful solution to a problem.

Although the same processes are used for all three aspects of intelligence universally, these processes are applied to different kinds of tasks and situations depending on whether a given problem requires analytical thinking, creative thinking, practical thinking, or a combination of these kinds of thinking. In particular, analytical thinking is invoked when components are applied to fairly familiar kinds of problems abstracted from everyday life. Creative thinking is invoked when the components are applied to relatively novel kinds of tasks or situations. Practical thinking is invoked when the components are applied to experience to adapt to, shape, and select environments. One needs creative skills and dispositions to generate ideas, analytical skills and dispositions to decide if they are good ideas, and practical skills and dispositions to implement one's ideas and to convince others of their worth.

Because the theory of successful intelligence comprises three subtheories—a componential subtheory dealing with the components of intelligence, an experiential subtheory dealing with the importance of coping with relative novelty and of automatization of information processing, and a contextual subtheory dealing with processes of adaptation, shaping, and selection—the theory has been referred to from time to time as *triarchic.*

Intelligence is not, as Edwin Boring (1923) once suggested, merely what intelligence tests test. Intelligence tests and other tests of cognitive and academic skills measure part of the range of intellectual skills. They do not measure the whole range. One should not conclude that a person who does not test well is not smart. Rather, one should merely look at test scores as one indicator among many of a person's intellectual skills. Moreover, the kinds of skills posited by hierarchical theories (e.g., Carroll 1993; Cattell 1971; Vernon 1971) are viewed only as a subset of the skills important in a broader conception of intelligence.

The Assessment of Successful Intelligence

Our assessments of intelligence have been organized around the analytical, creative, and practical aspects of it. We discuss those assessments here, singly and collectively.

Analytical Intelligence

Analytical intelligence is involved when the information-processing components of intelligence are applied to analyze, evaluate, judge, or compare and contrast. It typically is involved when components are applied to relatively familiar kinds of problems where the judgments to be made are of a fairly abstract nature.

In some early work, it was shown how analytical kinds of problems, such as analogies or syllogisms, can be analyzed componentially (Guyote and Sternberg 1981; Sternberg 1977, 1980b, 1983; Sternberg and Gardner 1983), with response times or error rates decomposed to yield their underlying information-processing components. The goal of this research was to understand the information-processing origins of individual differences in (the analytical aspect of) human intelligence. With componential analysis, one could specify sources of individual differences underlying a factor score such as that for "inductive reasoning." For example, response times on analogies (Sternberg 1977) and linear syllogisms (Sternberg 1980a) were decomposed into their elementary performance components. The general strategy of such research is to (a) specify an information-processing model of task performance; (b) propose a parameterization of this model, so that each information-processing component is assigned a mathematical parameter corresponding to its latency (and another corresponding to its error rate); and (c) construct cognitive tasks administered in such a way that it is possible through mathematical modeling to isolate the parameters of the mathematical model. In this way, it is possible to specify, in the solving of various kinds of problems, several sources of important individual or developmental differences: (1) What performance components are used? (2) How long does it take to execute each component? (3) How susceptible is each component to error? (4) How are the components combined into strategies? (5) What are the mental representations upon which the components act?

Research on the components of human intelligence yielded some interesting results. Consider some examples. First, execution of early components (e.g., inference and mapping) tends exhaustively to consider the attributes of the stimuli, whereas execution of later components (e.g., application) tends to consider the attributes of the stimuli in self-terminating fashion, with only those attributes processed that are essential for reaching a solution (Sternberg 1977). Second, in a study of the development of figural analogical reasoning, it was found that although children generally became quicker in information processing with age, not all components were executed more rapidly with age (Sternberg and Rifkin 1979). The encoding component first showed a decrease in component time with age and then an increase. Apparently, older children realized that their best strategy was to spend more time in encoding the terms of a problem so that they later would be able to spend less time in operating on these encodings. A related, third finding was that better reasoners tend to spend relatively more time than do poorer reasoners in global, up-front metacomponential planning, when they solve difficult reasoning problems. Poorer reasoners, on the other hand, tend to spend relatively more time in local planning (Sternberg 1981). Presumably, the better reasoners recognize that it is better to invest more time up front so as to be able to process a problem more efficiently later on. Fourth, it also was found in verbal analogical reasoning that as children grew older, their strategies shifted so that they relied on word association less and abstract relations more (Sternberg and Nigro 1980).

In the componential analysis work described above, correlations were computed between component scores of individuals and scores on tests of different kinds of psychometric abilities. First, in the studies of inductive reasoning (Sternberg 1977; Sternberg and Gardner 1983), it was found that although inference, mapping, application, comparison, and justification tended to correlate with such tests, the highest correlation typically was with the preparation-response component. This result was puzzling at first, because this component was estimated as the regression constant in the predictive regression equation. This result ended up giving birth to the concept of the metacomponents: higher-order processes used to plan, monitor, and evaluate task performance. Second, it was also found that the correlations obtained for all the components showed convergent-discriminant validation: They tended to be significant with psychometric tests of reasoning but not with psychometric tests of perceptual speed (Sternberg 1977; Sternberg and Gardner 1983). Third, significant correlations with vocabulary tended to be obtained only for encoding of verbal stimuli (Sternberg 1977; Sternberg and Gardner 1983). Fourth, it was found in studies of linear-syllogistic reasoning (e.g., *John is taller than Mary; Mary is taller than Susan; who is tallest?*) that components of the proposed (mixed linguistic-spatial) model that were supposed to correlate with verbal ability did so and did not correlate with spatial ability; components that were supposed to correlate with spatial ability did so and did not correlate with verbal ability. In other words, it was possible successfully to validate the proposed model of linear-syllogistic reasoning not only in terms of the fit of response-time or error data to the predictions of the alternative models but also in terms of the correlations of component scores with psychometric tests of verbal and spatial abilities (Sternberg 1980a). Fifth and finally, it was found that there were individual differences in strategies in solving linear syllogisms, whereby some people used a largely linguistic model, others a largely spatial model, and most the proposed linguistic-spatial mixed model. Thus, sometimes, less than perfect fit of a proposed model to group data may reflect individual differences in strategies among participants.

Creative Intelligence

Intelligence tests contain a range of problems, some of them more novel than others. In some of the componential work, we have shown that when one goes beyond the range of unconventionality of the conventional tests of intelligence, one starts to tap sources of individual differences measured little or not at all by the tests. According to the theory of successful intelligence, (creative) intelligence is particularly well measured by problems assessing how well an individual can cope with relative novelty (see Sternberg et al. 2002).

We presented 80 individuals with novel kinds of reasoning problems that had a single best answer. For example, they might be told that some objects are green and others blue; but still other objects might be grue, meaning green until the year 2000 and blue thereafter, or bleen, meaning blue until the year 2000 and green thereafter. Or they might be told of four kinds of people on the planet Kyron, blens, who are born young and die young; kwefs, who are born old and die old; balts, who are born young and die old; and prosses, who are born old and die young (Sternberg 1982; Tetewsky and Sternberg 1986). Their task was to predict future states from past states, given incomplete information. In another set of studies, 60 people were given more conventional kinds of inductive reasoning problems, such as analogies, series completions, and classifications, but were told to solve them. But the problems had premises preceding them that were either conventional (dancers wear shoes) or novel (dancers eat shoes). The participants had to solve the problems as though the counterfactuals were true (Sternberg and Gastel 1989a, b).

In these studies, we found that correlations with conventional kinds of tests depended on how novel or non-entrenched the conventional tests were. The more novel are the items, the higher are the correlations of our tests with scores on successively more novel conventional tests. Thus, the components isolated for relatively novel items would tend to correlate more highly with more unusual tests of fluid abilities (e.g., that of Cattell and Cattell 1973) than with tests of crystallized abilities. We also found that when response times on the relatively novel problems were componentially analyzed, some components better measured the creative aspect of intelligence than did others. For example, in the "grue-bleen" task mentioned above, the information-processing component requiring people to switch from conventional green-blue thinking to grue-bleen thinking and then back to green-blue thinking again was a particularly good measure of the ability to cope with novelty.

In our original work with divergent reasoning problems having no one best answer, we asked 63 people to create various kinds of products (Lubart and Sternberg 1995; Sternberg and Lubart 1991, 1995, 1996) where an infinite variety of responses were possible. Individuals were asked to create products in the realms of writing, art, advertising, and science. In writing, they were asked to write very short stories for which we would give them a choice of titles, such as "Beyond the Edge" or

"The Octopus's Sneakers." In art, the participants were asked to produce art compositions with titles such as "The Beginning of Time" or "Earth from an Insect's Point of View." In advertising, they were asked to produce advertisements for products such as a brand of bow tie or a brand of doorknob. In science, they were asked to solve problems such as one asking them how people might detect extraterrestrial aliens among us who are seeking to escape detection. Participants created two products in each domain.

First, we found that creativity comprises the components proposed by their investment model of creativity: intelligence, knowledge, thinking styles, personality, and motivation. Second, we found that creativity is relatively although not wholly domain-specific. Correlations of ratings of the creative quality of the products across domains were lower than correlations of ratings and generally were at about the .4 level. Thus, there was some degree of relation across domains at the same time that there was plenty of room for someone to be strong in one or more domains but not in others. Third, we found a range of correlations of measures of creative performance with conventional tests of abilities. As was the case for the correlations obtained with convergent problems, correlations were higher to the extent that problems on the conventional tests were nonentrenched. For example, correlations were higher with fluid than with crystallized ability tests, and correlations were higher, the more novel the fluid test was. These results suggest that tests of creative intelligence have some overlap with conventional tests (e.g., in requiring verbal skills or the ability to analyze one's own ideas—Sternberg and Lubart 1995) but also tap skills beyond those measured even by relatively novel kinds of items on the conventional tests of intelligence.

Practical Intelligence

Practical intelligence involves individuals applying their abilities to the kinds of problems that confront them in daily life, such as on the job or in the home. Practical intelligence involves applying the components of intelligence to experience so as to (a) adapt to, (b) shape, and (c) select environments. People differ in their balance of adaptation, shaping, and selection and in the competence with which they balance among the three possible courses of action.

Much of our work on practical intelligence has centered on the concept of tacit knowledge. We have defined this construct as what one needs to know in order to work effectively in an environment that one is not explicitly taught and that often is not even verbalized (Sternberg et al. 2000; Sternberg and Hedlund 2002; Sternberg and Wagner 1993; Sternberg et al. 1993; Sternberg et al. 1995; Wagner 1987; Wagner and Sternberg 1986; Williams et al. 2002). We represent tacit knowledge in the form of production systems or sequences of "if-then" statements that describe procedures one follows in various kinds of everyday situations.

We typically have measured tacit knowledge using work-related problems that present problems one might encounter on the job. We have measured tacit knowledge for both children and adults, and among adults, for people in over two-dozen occupations, such as management, sales, academia, teaching, school administration, secretarial work, and the military. In a typical tacit-knowledge problem, people are asked to read a story about a problem someone faces and to rate, for each statement in a set of statements, how adequate a solution the statement represents.

In the tacit-knowledge studies, first we have found that practical intelligence as embodied in tacit knowledge increases with experience, but it is profiting from experience, rather than experience per se, that results in increases in scores. Some people could have been in a job for years and still have acquired relatively little tacit knowledge. Second, we also have found that subscores on tests of tacit knowledge—such as for managing oneself, managing others, and managing tasks—correlate significantly with each other. Third, scores on various tests of tacit knowledge, such as for academics and managers, are also correlated fairly substantially (at about the .5 level) with each other. Thus, fourth, tests of tacit knowledge may yield a general factor across these tests.

However, fifth, scores on tacit-knowledge tests do not correlate with scores on conventional tests of intelligence, whether the measures used are single-score measures of multiple-ability batteries. Thus, any general factor from the tacit-knowledge tests is not the same as any general factor from tests of academic abilities (suggesting that neither kind of *g* factor is truly general but rather general only across a limited range of measuring instruments). Sixth, despite the lack of correlation of practical-intellectual with conventional measures, the scores on tacit-knowledge tests predict performance on the job as well as or better than do conventional psychometric intelligence tests. Seventh, in one study done at the Center for Creative Leadership, we further found that scores on our tests of tacit knowledge for management were the best single predictor of performance on a managerial simulation. In a hierarchical regression, scores on conventional tests of intelligence, personality, styles, and interpersonal orientation were entered first and scores on the test of tacit knowledge were entered last. Scores on the test of tacit knowledge were the single best predictor of managerial simulation score. Moreover, these scores also contributed significantly to the prediction even after everything else was entered first into the equation.

Eighth, in work on military leadership (Hedlund et al. 2003; Sternberg and Hedlund 2002; Sternberg et al. 2000), it was found that scores of 562 participants on tests of tacit knowledge for military leadership predicted ratings of leadership effectiveness, whereas scores on a conventional test of intelligence and on a tacit-knowledge test for managers did not significantly predict the ratings of effectiveness. In work with Eskimos (Grigorenko et al. 2004), it was found that low achievers in school can have exceptionally high practical adaptive skills at home.

Even stronger results have been obtained overseas. In a study in Usenge, Kenya, near the town of Kisumu, we were interested in school-age children's ability to adapt to their indigenous environment. We devised a test of practical intelligence for adaptation to the environment (see Sternberg and Grigorenko 1997; Sternberg, Nokes et al. 2001b; and Sternberg 2004, 2007 for more examples of cultural work relevant to the theory). The test of practical intelligence measured children's informal tacit knowledge for natural herbal medicines that the villagers believe can be used to fight various types of infections.

We found no correlation between the test of indigenous tacit knowledge and scores on the fluid-ability tests. But to our surprise, we found statistically significant correlations of the tacit-knowledge tests with the tests of crystallized abilities. The correlations, however, were *negative*. In other words, the higher the children scored on the test of tacit knowledge, the lower they scored, on average, on the tests of crystallized abilities.

We have considered each of the aspects of intelligence separately. How do they fare when they are assessed together?

All Three Aspects of Intelligence Together

Internal Validity Studies Several separate factor-analytic studies support the internal validity of the theory of successful intelligence.

In one study (Sternberg et al. 1999), we used the so-called Sternberg Triarchic Abilities Test (STAT—Sternberg 1993) to investigate the internal validity of the theory. Three hundred twenty-six high-school students, primarily from diverse parts of the United States, took the test, which comprised 12 subtests in all. There were four subtests each measuring analytical, creative, and practical abilities. For each type of ability, there were three multiple-choice tests and one essay test. The multiple-choice tests, in turn, involved, respectively, verbal, quantitative, and figural content.

Confirmatory factor analysis on the data was supportive of the triarchic theory of human intelligence, yielding separate and uncorrelated analytical, creative, and practical factors. The lack of correlation was due to the inclusion of essay as well as multiple-choice subtests. Although multiple-choice tests tended to correlate substantially with multiple-choice tests, their correlations with essay tests were much weaker. The multiple-choice analytical subtest loaded most highly on the analytical factor, but the essay creative and practical subtests loaded most highly on their respective factors. Thus, measurement of creative and practical abilities probably ideally should be accomplished with other kinds of testing instruments that complement multiple-choice instruments.

External Validity Studies We have also looked at the external validity of tests assessing successful intelligence.

The Rainbow Project In a study supported by the College Board (Sternberg and the Rainbow Project Collaborators 2006), we used an expanded set of tests on 1,015 students at 15 different institutions (13 colleges and 2 high schools). Our goal was not to replace the SAT but to devise tests that would supplement the SAT, measuring skills that this test does not measure. In addition to the multiple-choice STAT tests described earlier, we used 3 additional measures of creative skills and 3 of practical skills:

Creative Skills The three additional tests were captioning cartoons, writing creative short stories using two of a number of suggested titles, and orally telling creative stories based on a picture.

Practical Skills The three additional tests were everyday situational judgments based on movie scenarios, a common-sense questionnaire based on problems found in work life, and a common-sense questionnaire based on problems confronted in school.

We found that our tests significantly and substantially improved upon the validity of the SAT for predicting first-year college grades (Sternberg and the Rainbow Project Collaborators 2006). The test also improved equity: using the test to admit a class would result in greater ethnic diversity than would using just the SAT or just the SAT and grade-point average.

The Kaleidoscope Project The Kaleidoscope Project (Sternberg 2005, 2010; Sternberg et al. 2012) has been used over the past 5 years to admit undergraduate students to Tufts University. Each year, all 15,000+ applicants are given a selection of essays assessing analytical, creative, practical, and also wisdom-based skills. The applicants have the option of completing one of the essays, and then the analytical, creative, practical, and wisdom-based skills demonstrated through these essays and other aspects of the application are rated.

The exact Kaleidoscope prompts vary from year to year (see Sternberg 2010 for a complete list through 2009). The questions differ in the skills they emphasize. No question is a "pure" measure of any single component of successful intelligence. Scoring of the exercises is holistic and is completed by admissions officers using rubrics with which they were provided by the Center for the Psychology of Abilities, Competencies, and Expertise at Tufts (PACE Center). We have found that with training, admissions officers can achieve good inter-rater reliability (consistency) in their evaluations.

The results at Tufts illustrated that a highly selective college can introduce an "unconventional" exercise into its undergraduate admissions process without disrupting the quality of the entering class. It is important to underscore the point that academic achievement has always been and remains the most important dimension of Tufts' undergraduate admissions process. Since we introduced the Kaleidoscope pilot in 2006, applications have remained roughly steady or increased slightly, and the mean SAT scores of accepted and enrolling students increased to new highs. In addition, we have not detected statistically meaningful ethnic group differences on the Kaleidoscope measures. Controlling for the academic rating given to applicants by admissions officers (which combines information from the transcript and standardized tests), students rated for Kaleidoscope achieved significantly higher academic averages in their undergraduate work than students who were not so rated by the admissions staff. In addition, research found that students with higher Kaleidoscope ratings were more involved in, and reported getting more out of, extracurricular, active-citizenship and leadership activities in their first year at Tufts.

In sum, as Tufts seeks to identify and develop new leaders for a changing world, Kaleidoscope provides a vehicle to help identify the potential leaders who may be best positioned to make a positive and meaningful difference to the world in the future. In the fast-paced, data-driven atmosphere of highly competitive college admissions, Kaleidoscope validates the role of qualitative measures of student ability and excellence.

Instruction for Successful Intelligence

Instructional studies are a further means of testing the theory (Sternberg & Grigorenko 2007; Sternberg et al. 2001a, 2008, 2009).

Several sets of studies investigated instruction for academic skills. Four sets are briefly described here.

In a first set of studies, researchers explored the question of whether conventional education in school systematically discriminates against children with creative and practical strengths (Sternberg and Clinkenbeard 1995; Sternberg et al. 1996, 1999). Motivating this work was the belief that the systems in most schools strongly tend to favor children with strengths in memory and analytical abilities.

The investigators used the Sternberg Triarchic Abilities Test in some of their instructional work. The test was administered to 326 children around the United States and in some other countries who were identified by their schools as gifted by any standard whatsoever. Children were selected for a summer program in (college-level) psychology if they fell into one of five ability groupings: high analytical, high creative, high practical, high balanced (high in all three abilities), or low balanced (low in all three abilities). Students who came to Yale were then divided into four instructional groups. Students in all four instructional groups used the same introductory-psychology textbook (a preliminary version of Sternberg (1995)) and listened to the same psychology lectures. What differed among them was the type of afternoon discussion section to which they were assigned. They were assigned to an instructional condition that emphasized either memory, analytical, creative, or practical instruction. For example, in the memory condition, they might be asked to describe the main tenets of a major theory of depression. In the analytical condition, they might be asked to compare and contrast two theories of depression. In the creative condition, they might be asked to formulate their own theory of depression. In the practical condition, they might be asked how they could use what they had learned about depression to help a friend who was depressed.

Students in all four instructional conditions were evaluated in terms of their performance on homework, a midterm exam, a final exam, and an independent project. Each type of work was evaluated for memory, analytical, creative, and practical quality. Thus, all students were evaluated in exactly the same way.

Our results suggested the utility of the theory of successful intelligence. This utility showed itself in several ways.

First, we observed when the students arrived at Yale that the students in the high creative and high practical groups were much more diverse in terms of racial, ethnic, socioeconomic, and educational backgrounds than were the students in the high-analytical group, suggesting that correlations of measured intelligence with status variables such as these may be reduced by using a broader conception of intelligence. Thus, the kinds of students identified as strong differed in terms of populations from which they were drawn in comparison with students identified as strong solely by analytical measures. More importantly, just by expanding the range of abilities measured, the investigators discovered intellectual strengths that might not have been apparent through a conventional test.

Second, we found that all three ability tests—analytical, creative, and practical—significantly predicted course performance. When multiple-regression analysis was used, at least two of these ability measures contributed significantly to the prediction of each of the measures of achievement. Perhaps as a reflection of the difficulty of deemphasizing the analytical way of teaching, one of the significant predictors was always the analytical score. (However, in a replication of our study with low-income African-American students from New York, Deborah Coates of the City University of New York found a different pattern of results. Her data indicated that the practical tests were better predictors of course performance than were the analytical measures, suggesting that what ability test predicts what criterion depends on population as well as mode of teaching.)

Third and most importantly, there was an aptitude-treatment interaction whereby students who were placed in instructional conditions that better matched their pattern of abilities outperformed students who were mismatched. In other words, when students are taught in a way that fits how they think, they do better in school. Children with creative and practical abilities, who are almost never taught or assessed in a way that matches their pattern of abilities, may be at a disadvantage in course after course, year after year.

A follow-up study (Sternberg et al. 1998) examined learning of social studies and science by third graders and eighth graders. The 225 third graders were students in a very low-income neighborhood in Raleigh, North Carolina. The 142 eighth graders were students who were largely middle to upper-middle class studying in Baltimore, Maryland, and Fresno, California. In this study, students were assigned to one of three instructional conditions. In the first condition, they were taught the course that basically they would have learned had there been no intervention. The emphasis in the course was on memory. In the second condition, students were taught in a way that emphasized critical (analytical) thinking. In the third condition, they were taught in a way that emphasized analytical, creative, and practical thinking. All students' performance was assessed for memory learning (through multiple-choice assessments) as well as for analytical, creative, and practical learning (through performance assessments).

As expected, students in the successful-intelligence (analytical, creative, practical) condition outperformed the other students in terms of the performance assessments. One could argue that this result merely reflected the way they were taught. Nevertheless, the result suggested that teaching for these kinds of thinking succeeded. More important, however, was the result that children in the successful-intelligence condition outperformed the other children even on the multiple-choice memory tests. In other words, to the extent that one's goal is just to maximize children's memory for information, teaching for successful intelligence is still superior. It enables children to capitalize on their strengths and to correct or to compensate for their weaknesses, and it allows children to encode material in a variety of interesting ways.

We extended these results to reading curricula at the middle-school and the high-school level. In a study of 871 middle-school students and 432 high-school students, we taught reading either triarchically or through the regular curriculum. At the middle-school level, reading was taught explicitly. At the high-school level, reading was infused into instruction in mathematics, physical sciences, social sciences, English, history, foreign languages, and the arts. In all settings, students who were taught triarchically substantially outperformed students who were taught in standard ways (Grigorenko et al. 2002).

The largest-scale study, described in Sternberg et al. (2008), was conducted with 196 teachers and 7,702 students. The study spanned 4 years, 9 states, 14 school districts, and 110 schools. It showed that with many thousands of fourth graders, it was possible to obtain gains in fourth-grade reading and mathematics that were greater for triarchic instruction for critical thinking or memory. This study suggested that triarchic instruction can be "scaled up" to reach children across a wide variety of geographic areas as well as subject matter areas.

Thus, the results of these sets of studies suggest that the theory of successful intelligence is valid as a whole. Moreover, the results suggest that the theory can make a difference not only in laboratory tests but in school classrooms and even the everyday life of adults as well.

Conclusions

This chapter has presented the theory of successful intelligence. Some psychologists believe the theory departs too much from the conventional theory of general intelligence (i.e., the theory of Spearman 1904, 1927). Some disagree with the theory (Gottfredson 2003a, b; Jensen 1998). Others believe the theory does not depart from conventional *g* theory enough (Gardner 1983, 2006). Still others have theories that are more compatible, in spirit, with that proposed here, at least for intelligence (Ceci 1996). The theory is rather newer than that of, say, Spearman (1904) and has much less work to support it as well as a lesser range of empirical support. I doubt the theory is wholly correct—scientific theories so far have not been—but I hope at the same time it serves as a broader basis for future theories than, say, Spearman's theory of general intelligence. No doubt, there will be those who wish to preserve this and related older theories, and those who will continue to do research that replicates hundreds and thousands of time that so-called general intelligence does indeed matter for success in many aspects of life. I agree. At the same time, I suspect it is not sufficient and also that those who keep replicating endlessly the findings of the past are unlikely to serve as the positive intellectual leaders of the future. But only time will tell. As noted earlier, there is typically some value to replication in science, although after a point is established, it seems more to continue to produce papers than to produce new scientific breakthroughs.

The educational system in the United States, as in many other countries, places great emphasis on instruction and assessments that tap into two important skills: memory and analysis. Students who are adept at these two skills tend to profit from the educational system, because the ability tests, instruction, and achievement tests we use all largely measure products and processes emanating from these two kinds of skills. There is a problem, however, namely, that children whose strengths are in other kinds of skills may be shortchanged by this system. These children might learn and test well, if only they were given an opportunity to play to their strengths rather than their weaknesses.

As a society, we can create a closed system that advantages only certain types of children and that disadvantages other types. Children who excel in memory and analytical abilities may end up doing well on ability tests and achievement tests and hence find the doors of opportunity open to them. Children who excel in other abilities may end up doing poorly on the tests and find the doors shut. By treating children with alternative patterns of abilities as losers, we may end up creating harmful self-fulfilling prophecies.

Institutions should consider pooling their resources and developing a common model and common methods of assessment. By working separately, they fail to leverage their strengths and to share information regarding the best ways to make decisions. In essence, each institution "reinvents the wheel." A consortium would be far more powerful than each institution working on its own. Successful intelligence is one model such a consortium might use. Doubtless there are many others. The important thing is to work together toward a common good—toward devising the best ways to select students so as to maximize their positive future impact. We all wish our intellectual leaders to show wisdom. We ourselves need to do the same.

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17 Emotional and Social Intelligence and Behavior

Richard E. Boyatzis, James Gaskin, and Hongguo Wei

Of the various levels at which emotional intelligence (EI) and social intelligence (SI) exist within a person, the behavioral level has received the least amount of attention in academic research but holds the most promise for a concept and measurement approach that relates to job and life outcomes, as well as allowing others to "see" EI and SI in action (Goleman 1998; Boyatzis 2009; Cherniss 2010). Emotional intelligence (EI) manifests itself at many levels within a person (Cherniss and Boyatzis 2013). In the past, discussion of EI was often focused on the different theoretical models and different ways of assessing EI (Matthews et al. 2004). In this chapter, we will review the major models or theories which constitute levels of EI and SI and the tests appearing in research publications. The chapter will then focus on the behavioral level and the measurement at this level currently most in use.

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A Review of Various Theoretical and Methodological Approaches to EI

To offer a brief review, expanding on Fernandez-Berrocal and Extremera (2006), Boyatzis (2009), and Cherniss (2010), the three major theoretical approaches to EI are described below. Within each theory, we further briefly describe the measures currently appearing in publications. A framework, or grand theory of EI, is offered in Fig. 17.1 to suggest where the ability, self-perception, and behavioral levels coexist (Cherniss and Boyatzis 2013).

Ability-Based Level of EI

Most credit Salovey and Mayer (1990) with the first use of the phrase "emotional intelligence" in a published article. They defined EI as "the subset of social intelligence that involves the ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions" (Salovey and Mayer 1990). It is based on the view of emotional processes as relying on complex neural activities and as motives to be intelligent (Leeper 1948). It is a type of "emotional information processing" (Salovey and Mayer 1990). They further clarified EI as "the ability to perceive and express emotion, assimilate

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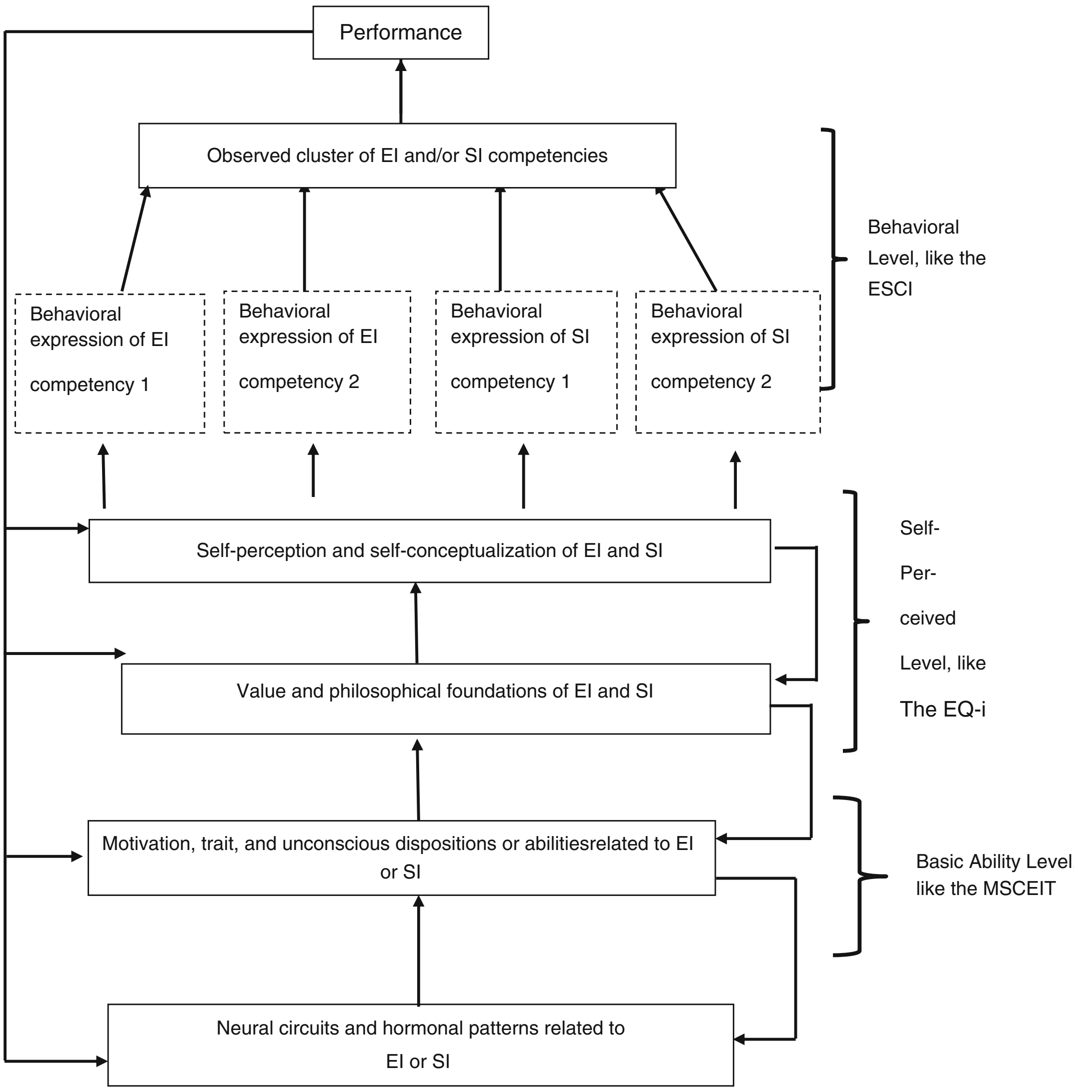

Fig. 17.1 Emotional intelligence (EI), social intelligence (SI), and emotional and social competencies as multiple levels within the personality structure (appearing in Cherniss and Boyatzis (2013) adapted from Boyatzis et al. (2000) and Boyatzis (2009))

emotion in thought, understand and reason." In their theory, Mayer and Salovey (1997) claim that EI is comprised of four dimensions: emotion perception, emotion understanding, emotional facilitation, and emotion regulation.

The measure used most often to examine this approach (EI) is the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT). It is a direct performance assessment of emotional processing with some scenarios testing (Mayer et al. 1999; Salovey and Mayer 1997). It is scored in two ways which has caused some confusion: consensus and expert scoring. Because they define EI as a type of cognitive intelligence, it should correlate with cognitive ability (Joseph and Newman 2010). The MSCEIT has content validity (Cherniss 2010). Reliability of the MSCEIT is appropriate, with split-half estimates for the whole scale of .91 and .93 (Mayer et al. 2003). Test-retest reliability has been estimated as $r = .86$

($N = 60$) (Brackett and Mayer 2003). The overall internal consistency reliabilities are usually above .75, although the reliabilities of the subscales have not been as good (Conte 2005; Matthews et al. 2002).

A CFA does not support their 4-factor model (Gignac 2005; Rossen et al. 2008). The MSCEIT seems to have discriminant validity with tests of personality. For instance, MSCEIT factors have the strongest correlations with agreeableness from the Big Five ($r = .21–.28$), while their correlations with the other four personality factors are less than .20 (Mayer et al. 2008).

The low correlations between MSCEIT factors and relevant constructs impair the convergent validity for the MSCEIT. "Convergent validity for the MSCEIT seems more problematic…. On the other hand, the MSCEIT correlates with measures of verbal intelligence (r = .36) and with other kinds of intelligence (r = .10 to .20) at the levels one would want from a form of intelligence that is supposed to be related to but distinct from other types of intelligence" (Cherniss 2010). For instance, as a form of emotional intelligence measure, MSCEIT is supposed to be moderately correlated but distinct with other emotional perception constructs. However, Roberts et al. (2006) found that the Japanese and Caucasian Brief Affect Recognition Test (JACBART) has low correlations with the overall MSCEIT scale and its subscales ($r = .20–.26$) and does not correlate with the emotional perception scale of the MSCEIT at all ($r = .00$). Similarly, the MSCEIT subscales have correlations with the levels of emotional awareness scale (LEAS) from .15 to .20 (Ciarrochi et al. 2003). These results suggest that the MSCEIT has weak or little convergent validity with other relevant emotional constructs.

The incremental validity of the MSCEIT is quantitatively supported. With a student sample, Rossen and Kranzler (2009) found that after controlling for general mental ability and personality, EI measured with the MSCEIT explained incremental variance to positive relationships with others and alcohol use.

Criticism from those other than skeptics of EI in general has focused more on the measure than the concept. That said, the model does seem too restricted to some. Several emotional-related qualities commonly ascribed to EI are excluded, such as "emotional expressiveness, empathy, perspective-taking, self-control, and implicit emotional skills" (Matthews et al. 2006, p. 106). For example, the 4-factor model does not seem plausible. A CFA analysis shows that "the non-constrained 4-factor model yield a non-positive definite matrix, which was interpreted to be due to the fact that two of the branch-level factors (perceiving and facilitating) are collinear" (Gignac 2005, p. 233). Two other studies replicated Gignac's (2005) results (Palmer et al. 2005; Rossen et al. 2008). In addition, the scoring system is complicated (MacCann and Roberts 2008). It is difficult to tell whether a test item is appropriately answered (Matthews et al. 2006). In order to solve this problem, it takes two different approaches in the scoring system: consensus scoring and expert scoring. Although these two scoring approaches are highly correlated ($r = .96–.98$), "it is unclear whether a person who thinks about the emotional domain differently from experts or from the average of several peers is low on that ability or whether that person simply has a new (and perhaps better) way of thinking" (Murphy 2006, p. 348).

The format of the MSCEIT has been compared to knowledge tests of EI, which may not provide an appropriate assessment of a person's actual ability (Cherniss 2010). "The assessment of knowledge in the abstract does not reflect the live performance of EI in the rich social situation of real life … one might understand that smiling at someone can be an effective means of producing a positive emotional reaction, but recognizing in a live encounter the moment to smile and doing so in a way that does not seem false or insincere may well be a different ability" (Spector and Johnson 2006, p. 335).

The Schutte Self-Report Emotional Intelligence Test (SREIT) is a self-report scale to measure "a homogeneous construct of emotional intelligence" based on Mayer-Salovey-Caruso model (Schutte et al. 1998). It has 33 items. This test will be reviewed here, but all of the characteristics and criticisms of the self-perception methods described in the next segment apply to this test because the method of assessment is self-report (Schutte et al. 1998).

The SREIT appears to be a face-valid measure of EI (Petrides and Furnham 2000). It has internal consistency (i.e., Cronbach's alpha) of .90 for the 33 items (Schutte et al. 1998). A 2-week test-retest reliability is adequate ($r = .78$) (Conte and Dean 2006). Research results on discriminant validity have been mixed. In an initial small study with 23 college students, the SREIT's correlation with openness to experience was high ($r = .54$), but the absolute correlations with other Big Five personality factors were lower ($r = .21–.28$) (Schutte et al. 1998). However, in one larger study, the SREIT's correlations with the Big Five were from .18 (agreeableness) to .51 (extraversion) (Saklofske et al. 2003). Results from these two studies show that the correlations between SREIT and the Big Five personality factors were not consistent across different samples. In a different study, the correlation between SREIT and psychological well-being was pretty high ($r = .70$) (Brackett and Mayer 2003), which implies that the SREIT is possibly a different measure of psychological well-being.

Since the SREIT is believed to be measuring a type of intelligence, it should have a moderate correlation with the general intelligence (Cherniss 2010). However, a study shows that the SREIT was not significantly correlated with cognitive ability (Saklofske et al. 2003), which suggests that the SREIT did not have the acceptable convergent validity.

The criticisms again as with the MSCEIT focus more on the measure than the concept. For example, it was said that the SREIT cannot measure a general EI factor because the test is not unifactorial (Petrides and Furnham 2000). The 33 items of Schutte's test came from all three subcategories of Salovey and Mayer's original EI model. However, in the analysis, Schutte failed to demonstrate the three subdimensions of EI as separate (Petrides and Furnham 2000). "It would have been more appropriate to perform a factor analysis on the 62 items, rather than a component analysis" (Gignac et al. 2005, p. 1030). Furthermore, it was claimed that the factors should have been rotated obliquely, not orthogonally (Petrides and Furnham 2000).

Another self-assessment test that was based on the MSCEIT model was by Wong and Law which offered "a set of interrelated abilities possessed by individuals to deal with emotions" (Wong and Law 2002; Law et al. 2004). Their construct has four dimensions: self-emotional appraisal, others' emotional appraisal, regulation of emotion, and use of emotion. Their test, the WLEIS, is composed of 16 items. With two samples, the authors showed convergent, discriminant, and incremental validity of this 16-item EI scale (Wong and Law 2002). Their empirical analysis shows that EI has "incremental predictive power over life satisfaction." After controlling for Big Five personality, both the student sample and the work samples showed that others' ratings of EI explained additional variance (Law et al. 2004). All of the criticisms of self-assessment explained in the next section also apply to their test, with the additional major issue that it is only 16 items which dramatically limits the scope of the assessment.

Self-perception Level of EI

Reuven Bar-On developed a model on "an array of non-cognitive capabilities, competencies, and skills that influence one's ability to succeed in coping with environmental demands and pressures" (1997, p. 14). The components included five subtypes of EI: intrapersonal intelligence, interpersonal intelligence, adaptability, stress management, and general mood (Bar-On 1997, 2006). The test, the Emotional Quotient Inventory, is composed of 15 scales in four composites: self-perception includes emotional self-awareness, self-regard, and self-actualization; self-expression includes assertiveness, emotional expression, and independence; interpersonal includes empathy, interpersonal relationships, and social responsibility; decision making includes problem solving, reality testing, and impulse control; stress management includes optimism, flexibility, and stress tolerance. The EQ-i was originally a self-report; in 1997, the 360 version was introduced (Bar-On 1997).

Since the model on which it was based and most, if not all, of the research reported in journals and book chapters to date is from the self-assessment version, it is included in this section. To the extent the published research appears using the 360 version or Bar-On changes his model, it could be included in the subsequent behavioral level section as well.

The EQ-i has good internal consistency. With 243 university students, a study shows that the internal consistency reliability ranged from .69 to .96, with an overall estimate of .96 (Dawda and Hart 2000). Another recent study in North America showed an internal consistency of .97, and a 6-month test-retest reliability of .72 for men ($n=73$) and .80 for women ($n=279$) (Bar-On 2004). However, the internal structure of EQ-i is not consistent. An EFA with a varimax rotation generated a 13-factor model rather than the 15-factor model in Bar-On theory. After removing the problematic factors, a CFA generates a 10-factor model (Bar-On 2006).

Although Bar-On theory was "designed to examine … a conceptual model of emotional and social functioning" (Bar-On 2006, p. 15), the criticism of this approach has been focusing on its overly broad conceptualization (Murphy 2006). Others have claimed that EQ-i has a great deal of overlap with personality, "predictive validity may simply be a consequence of the EQ-i functioning as a proxy measure of personality" (Matthews et al. 2004, p. 16). Thus, the content validity of EQ-i is doubtful given that it includes nonability personality traits and ignores some essential EI factors such as emotional understanding and emotional perception (Cherniss 2010).

The construct validity of Bar-On model and the test confirm that he/she is testing ESC, which is similar to Boyatzis and Goleman model to be explained in the next section as described by Cherniss (2010). An empirical study confirms that EQ-i has convergent validities "with respect to measures of normal personality, depression, somatic symptomatology, intensity of affective experience and alexithymia" (Dawda and Hart 2000, p. 797). Also, the EQ-i has been reported correlating well with some other self-report EI measures ($r=.58–.69$) (Bar-On 2004). However, because both convergent and discriminant validity are based on the correlation coefficients, an exceptional good convergent validity is a threat to the discriminant validity. Actually, evidence has shown that the EQ-i does not have good discriminant validity especially considering its relationship with personality variables. Bar-On (2006, p. 16) mentioned that the EQ-i overlaps with personality tests "probably no more than 15 % based on eight studies in which more than 1,700 individuals participated." However, one study shows that when using the Big Five predicts EQ-i scores, the multiple correlation is .79, which means the Big Five personality accounted for the majority of variance in the EQ-i (Grubb and McDaniel 2007).

Another self-assessment test but one based on a composite of the various models of all of the major EI authors is the TEIQue by Petrides and Furnham (2000, 2001, 2003). They claim to assess "trait EI" which they say is "a constellation of emotion-related self-perceived abilities and dispositions located at the lower levels of personality hierarchies" (Petrides and Furnham 2000). It is meant to include all "personality facets that are specifically related to affect" (Petrides et al. 2007, p. 274). The TEIQue has four subdimensions: emotionality, self-control, sociability, and well-being.

After controlling for the Big Five, the TEIQue has a positive relationship with happiness (Furnham and Petrides 2003). It is linked with distinctive reactivity to affect-laden information and has incremental validity over the Big Five (Petrides and Furnham 2003; Petrides et al. 2004). The TEIQue also has incremental validity over alexithymia and optimism (Mikolajczak et al. 2006, 2007).

The criticisms about the TEIQue are similar to those raised about the and self-assessment in general.

The Behavioral Level of EI and SI

The behavioral level has been the most discussed and documented as a "competency" approach (Boyatzis 2009; Cherniss 2010). A competency was originally defined as “an underlying ability that leads to or causes effective performance” (McClelland 1973; Boyatzis 1982; Spencer and Spencer 1993). The various competencies were described as a set of related behavior or actions organized around an underlying intent or context for their use. In this sense, the appearance of the behavior was described as “alternate manifestations” of the underlying characteristics (McClelland 1985).

For example, asking someone questions is an action. But someone can do this for multiple reasons or intent. Someone might ask questions to better understand someone. Another person, or the same person at another time, might ask questions as a way to convince someone else of a position on an issue. The former would result in the combination of intent and action to be labeled or coded as empathy, but the latter would be influence.

One explanation as to why these EI and SI competencies have such a strong relationship to life outcomes and job performance is that they were originally derived inductively by comparing effective and ineffective people in various occupations in a wide variety of organizations in many countries (Boyatzis 1982; Spencer and Spencer 1993; McClelland 1998; Goleman 1998). Outcome criteria or nominations were used to identify samples of people who were effective in a job and those who were not. Detailed collection of their behavior and thoughts using variations of critical incident interviews (Flanagan 1954; Boyatzis 1982; Spencer and Spencer 1993) or videotaped simulations enabled researchers to develop “codes” to determine whether or not a person was demonstrating these EI and SI competencies in various situations. For more detailed explanation of the methods, see Boyatzis (1982, 1998) or Spencer and Spencer (1993), or Boyatzis (2009) for a review of the methods.

Once these “codes” of competencies were applied in many settings and jobs, 360 assessments were developed to collect the observations from a broader array of sources and make the data collection easier (Boyatzis 2009). A 360 measurement is a multisource assessment in which people who live and work with a target person describe that person’s typical behavior through a series of questions. Items for the 360 were created based on the behavior validated in the earlier studies with a phrase added that provided the respondent with the intent. For example, the behavior of “listens attentively” was validated as an indicator of empathy in many of the competency studies. To include it in the 360, we added the intent. The item now reads, “Understands others by listening attentively.”

The most widely used and cited of the behavioral level approaches to EI comes from McClelland, Boyatzis, Goleman, Cherniss, and their colleagues at The Hay Group. Several definitions have appeared over the decades. One was that “Emotional intelligence [includes] abilities such as being able to motivate oneself and persist in the face of frustrations; to control impulse and delay gratification; to regulate one’s moods and keep distress from swamping the ability to think; to empathize and to hope” (Goleman 1995, p. 34). In describing their definitions of these clusters in detail, Boyatzis (2009) said, “(a) an emotional, intelligence competency is an ability to recognize, understand, and use emotional information about oneself that leads to or causes effective or superior performance; (b) a social intelligence competency is the ability to recognize, understand and use emotional information about others that leads to or causes effective or superior performance; and (c) a cognitive intelligence competency is an ability to think or analyze information and situations that leads to or causes effective or superior performance.”

In the Boyatzis and Goleman model, EI has two dimensions and SI has two dimensions: EI includes self-awareness and self-management and SI includes social awareness and relationship management. The Emotional and Social Competency Inventory (ESCI), or its university version (ESCI-U which includes two cognitive competencies), is more outcome oriented because of the way in which they were developed (Boyatzis and Goleman 1996, 1999; Wolff 2007, 2008; Hay Group 2011). Detailed statistical analysis and results about the psychometrics of the tests are summarized in the following section.

The ESCI assesses 12 competencies and the ESCI-U assesses 14 competencies. Past research has shown a set of competencies that differentiate outstanding and effective performers from others in many countries (Bray et al. 1974; Boyatzis 1982; Kotter 1982; Thornton and Byham 1982; Luthans et al. 1988; Howard and Bray 1988; Campbell et al. 1970; Spencer and Spencer 1993; Goleman 1998; Hopkins and Bilimoria 2008; Koman and Wolff 2008; Dreyfus 2008; Williams 2008; Sternberg 1996). They can be clustered into three sets of competencies, two of which are related to EI and SI: (1) cognitive competencies, such as systems thinking and pattern recognition; (2) emotional intelligence competencies, including self-awareness and self-management competencies, such as emotional self-awareness and emotional self-control, and what used to be a part of EI but is now separated for theoretical as well as empirical reasons; and (3) social intelligence competencies, including social awareness and relationship management competencies, such as empathy and teamwork. The specific competencies considered to be a behavioral approach to emotional, social, and cognitive intelligence are shown in Table 17.1.

The criticisms of this approach are that the concepts are over-inclusive (Matthews et al. 2004). Other criticisms of Matthews et al. (2004) have been addressed in publications in the last 8 years and are reviewed in this section of this chapter.

There has been one other measure appearing in selected publications which was developed to assess the behavioral level of EI. Dulewicz and Higgs (1999) developed a measure based on the work of Boyatzis (1982) and Boyatzis and Goleman (1996). They assessed being aware of and managing one's own feelings and emotions, being sensitive to and influencing others, sustaining one's motivation, and balancing one's motivation and drive with intuitive, conscientious, and ethical behavior (Dulewicz and Higgs 1999). Their measure, the EIQ, has seven dimensions: self-awareness, emotional resilience, motivation, interpersonal sensitivity, influence, intuitiveness, and conscientiousness (Higgs and Dulewicz 2002; Dulewicz et al. 2003). It is also a 360.

Table 17.1 The scales and clusters of the Emotional and Social Competency Inventory (ESCI and ESCI-U—the university version) (Boyatzis and Goleman 1996, 1999; Boyatzis et al. 2001, 2007)

Emotional intelligence competencies are as follows:
Self-awareness cluster: Concerns knowing one's internal states, preferences, resources, and intuitions. The self-awareness cluster contains one competency:
Emotional self-awareness: Recognizing one's emotions and their effects
Self-management cluster: Refers to managing one's internal states, impulses, and resources. The self-management cluster contains four competencies:
Emotional self-control: Keeping disruptive emotions and impulses in check
Adaptability: Flexibility in handling change
Achievement orientation: Striving to improve or meeting a standard of excellence
Positive outlook: Seeing the positive aspects of things and the future
Social intelligence competencies are as follows:
Social awareness cluster: Refers to how people handle relationships and awareness of others' feelings, needs, and concerns. The social awareness cluster contains two competencies:
Empathy: Sensing others' feelings and perspectives and taking an active interest in their concerns
Organizational awareness: Reading a group's emotional currents and power relationships
Relationship management cluster: Concerns the skill or adeptness at inducing desirable responses in others. The cluster contains five competencies:
Coach and mentor: Sensing others' development needs and bolstering their abilities
Inspirational leadership: Inspiring and guiding individuals and groups
Influence: Wielding effective tactics for persuasion
Conflict management: Negotiating and resolving disagreements
Teamwork: Working with others toward shared goals. Creating group synergy in pursuing collective goals
Cognitive intelligence competencies (in the ESCI university version only) are as follows:
Systems thinking: Perceiving multiple causal relationships in understanding phenomena or events
Pattern recognition: Perceiving themes or patterns in seemingly random items, events, or phenomena

The alpha for overall EIQ was .77. The alpha coefficients for each of the element scales ranged from .6 to .8 (Dulewicz and Higgs 2000). The EIQ was significantly related with performance measures (except for interpersonal sensitivity)

(Dulewicz and Higgs 2000). Dulewicz et al. (2003) tested EIQ's content, construct, and criterion-related validity and showed support.

The ESCI and ESCI-U

The ESCI is a 68-item test assessing the 12 EI and SI competencies listed in Table 17.1. The ESCI-U (university version) is a 70-item test assessing the 12 EI and SI competencies in Table 17.1, as well as the two CI (cognitive) competencies listed. The tests were designed to be used as 360, multisource rater instruments. In most research, only the "other" assessments from informants are used. The self-assessment is used primarily in applications in coaching, training, and college courses, along with the "other" assessments. The following statistical tests were computed on the ESCI with a sample of 5,761 self-assessments and 62,297 other assessments. The effective sample sizes for CFAs with no missing data were 4,468 and 25,057, respectively. The sample was generated from research studies and training programs with managers and professionals from many countries of the world. The following statistical tests were computed on the ESCI-U with a sample of 1,629 self-assessments and 21,288 other assessments. The effective sample sizes for CFAs with no missing data were 1,398 and 8,981, respectively. The ESCI-U sample was generated from research and graduate courses with MBAs from the Weatherhead School of Management at Case Western Reserve University.

Scale Reliabilities Using Alpha

Cronbach's alpha was computed for each scale shown in Table 17.2. As a comparison, the earlier version of the test, called the ECI-2 "others," showed an average alpha of 0.78 and since 2007 the ESCI "others" shows 0.87. Thus, the ESCI shows improved scale reliability as well as better factor structure. To support aggregation across various informant sources, inter-rater agreement scores (rWG(J)) were calculated. Badri (2013), using a sample of 468 respondents, reported the following rWG(J) for each competency: emotional self-awareness, 0.86; achievement orientation, 0.94; adaptability, 0.95; emotional self-control, 0.92; positive outlook, 0.95; empathy, 0.92; organizational awareness, 0.92; coach and mentor, 0.91; influence, 0.93; conflict management, 0.88; inspirational leadership, 0.94; and teamwork, 0.97.

Model Fit Using CFA

An exploratory factor analyses on each of the four data sets (ESCI self, ESCI others, ESCI-U self, and ESCI-U others) showed almost all of the items loaded on the appropriate, predicted scale (Boyatzis and Gaskin 2010; Hay Group 2011). Nonconforming items were dropped from the analysis. Several items which were close to the typical cutoffs were slightly reworded for future use of the test but kept in the subsequent analyses reported here. Confirmatory factor analyses were run on each of the four samples to assess the model fit to the 12 scales in the ESCI and 14 scales in the ESCI-U.

Except for the chi-square to df ratio for the ESCI self and other and ESCI-U other, all estimates of model fit were within acceptable standards to support the scales as an acceptable model. In the chi-square to df ratio case, it is believed that the large sample size contributed to an inflation of the chi-square, thus rendering that estimate less useful. Specifically, for the self and the other, independently calculated, for the ESCI and ESCI-U, the RMSEA, PCLOSE, CFI, PCFI, GFI, and SRMR are within desired levels for a satisfactory model fit. Prior to running the CFA, all subjects with missing data were eliminated, resulting in the smaller sample sizes reported in Table 17.3.

Convergent and Discriminant Validity of the Scales

PLS-GRAPH version 3.0 was used to determine the reliability and validity of the scales. Partial

Table 17.2 Cronbach's alpha for each scale in the ESCI and ESCI-U (sample sizes are shown in parentheses following the alpha)

	ESCI		ESCI-U	
	Self	Other	Self	Other
Emotional self-awareness	.754 (5,534)	.827 (42,215)	.771 (1,605)	.804 (16,223)
Emotional self-control	.854 (5,664)	.910 (56,713)	.843 (1,611)	.882 (17,993)
Achievement orientation	.800 (5,668)	.861 (47,975)	.705 (1,621)	.779 (18,381)
Adaptability	.720 (5,573)	.845 (53,875)	.752 (1,605)	.820 (16,914)
Positive outlook	.829 (5,641)	.883 (54,598)	.825 (1,606)	.846 (17,164)
Empathy	.708 (5,638)	.856 (52,138)	.725 (1,622)	.836 (17,520)
Organizational awareness	.786 (5,579)	.861 (54,475)	.764 (1,603)	.830 (17,159)
Influence	.721 (5,606)	.835 (50,702)	.746 (1,569)	.822 (14,693)
Teamwork	.771 (5,668)	.886 (58,911)	.775 (1,616)	.857 (18,354)
Coach and mentor	.856 (5,546)	.920 (48,744)	.821 (1,590)	.868 (15,369)
Conflict management	.682 (5,607)	.785 (51,948)	.636 (1,592)	.733 (16,252)
Inspirational leadership	.897 (5,221)	.887 (51,199)	.817 (1,536)	.866 (15,749)
Systems thinking	NA	NA	.794 (1,582)	.821 (15,176)
Pattern recognition	NA	NA	.792 (1,577)	.831 (13,502)

Table 17.3 Model fit using CFA using AMOS for the ESCI and ESCI-U both self and other responses for each

	ESCI		ESCI-U	
	Self	Other	Self	Other
Effective *n*	4,468	25,057	1,398	8,981
Chi-square	18,793	100,823	6,606	31,746
df	2,013	2,013	1,921	1,921
RMSEA	.043	.044	.042	.042
PCLOSE	1.000	1.000	1.000	1.000
CFI	.849	.910	.875	.919
PCFI	.797	.855	.808	.849
GFI	.861	.860	.862	.888
SRMR	.0536	.0424	.0469	.0319

least squares was used rather than the traditional covariance-based SEM tools such as LISREL or AMOS. PLS is especially well suited for working with new measures (Chin et al. 2003).

To test for convergent validity, items in each construct must have loadings over 0.5 (Fornell 1982; Hair et al. 1995) and composite reliabilities (CR) should be over 0.7 (Nunnally et al. 1994) and greater than their respective average variance extracted (AVE). Lastly, the average variance extracted should be maximized, with a minimum of 50 % (Barclay et al. 1995). Discriminant validity is established by showing that the correlation between any two constructs is less than the square root of the average variance extracted by the measures of that construct (Lim et al. 2006).[1]

As shown in Tables 17.4 through 17.7, for each of the scales in each of the analyses, all construct composite reliabilities, average variance extracted, and their relationship have met the respective thresholds to be considered sufficiently convergent. In addition, the square root of the average variance extracted was greater than the inter-scale correlations, showing discriminant validity for each of the scales for each of the analyses. These indicators of convergent and discriminant validity are shown for the ESCI self in Table 17.4, the ESCI other in Table 17.5, the ESCI-U self in Table 17.6, and for the ESCI-U

[1] Almost no one reports maximum shared variance any longer as an indication of discriminant validity, but for those aficionados who still use it, we have a different position. In many analyses of this type, another measure is also recommended for showing discriminant validity, called the maximum shared variance (MSV). But in this case, in which the theoretical model on which the items and scales were built is a circumplex model, it is assumed that some items, as well as scales, will have a high shared variance with others. For example, an expression or use of empathy is required to show inspirational leadership. As a result, the maximum shared variance of an item or scale will be deceptive and not an appropriate indicator of discriminant or discriminant validity.

Table 17.4 ESCI self: Convergent and discriminant validity using PLS ($n = 4{,}468$) [*square root of the AVE on the diagonal*]

Scale	μ	SD	CR	AVE	ESA	AO	ESC	A	PO	EMP	OA	IL	CFM	CM	TEAM
ESA	3.744	.817	.848	.521	**.722**										
AO	4.278	.695	.861	.554	.314	**.744**									
ESC	4.023	.698	.895	.631	.175	.221	**.794**								
A	4.127	.687	.826	.543	.301	.456	.368	**.737**							
PO	4.182	.683	.875	.540	.279	.409	.419	.427	**.735**						
EMP	3.983	.663	.819	.532	.448	.296	.441	.406	.380	**.729**					
OA	4.243	.670	.860	.551	.415	.319	.321	.474	.367	.482	**.742**				
IL	3.955	.743	.863	.652	.391	.483	.288	.497	.533	.428	.452	**.807**			
CFM	3.867	.745	.882	.627	.365	.369	.196	.344	.327	.357	.342	.445	**.792**		
CM	4.130	.747	.902	.697	.341	.447	.222	.350	.383	.379	.362	.598	.372	**.835**	
TEAM	4.338	.642	.856	.544	.355	.347	.407	.347	.420	.545	.455	.519	.323	.458	**.737**
INF	3.848	.773	.801	.575	.290	.280	.212	.378	.325	.320	.435	.413	.252	.363	.358

Table 17.5 ESCI Other: Convergent and discriminant validity using PLS convergent and discriminant validity using PLS ($n = 12{,}419$) [*square root of the AVE on the diagonal*]

Scale	μ	SD	CR	AVE	ESA	AO	ESC	A	PO	EMP	OA	IL	CFM	CM	**TEAM**
ESA	4.136	.795	.879	.549	**.741**										
AO	4.315	.768	.903	.608	.570	**.780**									
ESC	3.892	.844	.932	.697	.496	.498	**.835**								
A	4.058	.877	.891	.578	.586	.697	.590	**.760**							
PO	3.880	.852	.919	.654	.563	.626	.604	.685	**.808**						
EMP	3.806	.841	.889	.667	.711	.573	.637	.655	.623	**.817**					
OA	4.124	.815	.901	.645	.608	.579	.546	.705	.597	.700	**.803**				
IL	4.036	.850	.918	.692	.639	.714	.547	.734	.686	.710	.689	**.832**			
CFM	4.024	.889	.865	.617	.617	.601	.546	.648	.593	.668	.601	.689	**.786**		
CM	4.298	.758	.939	.720	.611	.678	.499	.635	.588	.674	.622	.796	.638	**.848**	
TEAM	4.192	.755	.920	.658	.650	.645	.659	.670	.674	.775	.692	.766	.667	.727	**.811**
INF	4.262	.802	.871	.575	.604	.582	.520	.678	.626	.656	.693	.688	.598	.629	.687

Table 17.6 ESCI-U self: Convergent and discriminant validity using PLS [*square root of the AVE on the diagonal*] ($n = 1{,}398$)

Scale	μ	SD	CR	AVE	A	AO	CFM	CM	EMP	ESA	ESC	INF	IL	OA	PO	PR	ST
A	4.010	.751	.850	.531	**.729**												
AO	4.159	.770	.821	.534	.592	**.731**											
CFM	3.678	.874	.880	.591	.493	.449	**.769**										
CM	3.717	.890	.884	.606	.407	.429	.482	**.779**									
EMP	3.945	.771	.816	.527	.449	.353	.446	.384	**.726**								
ESA	3.889	.839	.845	.525	.443	.453	.554	.445	.482	**.724**							
ESC	3.892	.827	.893	.677	.565	.345	.423	.309	.454	.326	**.823**						
INF	3.797	.810	.842	.516	.584	.546	.563	.525	.458	.526	.378	**.718**					
IL	3.675	.864	.878	.591	.527	.534	.540	.657	.428	.484	.369	.649	**.769**				
OA	4.118	.735	.855	.541	.547	.439	.455	.429	.489	.491	.383	.631	.546	**.736**			
PO	4.023	.821	.878	.591	.517	.510	.495	.463	.376	.445	.414	.448	.564	.410	**.768**		
PR	3.785	.876	.863	.559	.485	.431	.421	.339	.375	.455	.343	.536	.431	.393	.333	**.747**	
ST	3.841	.787	.871	.629	.544	.490	.418	.391	.456	.468	.367	.534	.455	.446	.359	.674	**.793**
TEAM	4.118	.742	.850	.533	.471	.440	.468	.525	.514	.460	.433	.510	.589	.550	.457	.339	.424

Table 17.7 ESCI-U other: Convergent and discriminant validity using PLS [*square root of the AVE on the diagonal*] ($n = 8{,}981$)

Scale	μ	SD	CR	AVE	A	AO	CFM	CM	EMP	ESA	ESC	INF	IL	OA	PO	PR	ST
A	4.192	.776	.884	.604	**.777**												
AO	4.330	.753	.871	.628	.747	**.792**											
CFM	3.969	.861	.911	.663	.640	.580	**.814**										
CM	4.079	.875	.906	.659	.655	.658	.658	**.812**									
EMP	4.034	.838	.885	.657	.677	.602	.671	.671	**.811**								
ESA	4.031	.841	.875	.585	.643	.607	.694	.634	.708	**.765**							
ESC	4.134	.820	.906	.707	.682	.575	.597	.555	.674	.598	**.841**						
INF	4.033	.816	.884	.603	.696	.657	.725	.700	.697	.693	.572	**.776**					
IL	4.032	.871	.906	.658	.695	.673	.691	.793	.704	.668	.595	.758	**.811**				
OA	4.290	.751	.886	.608	.742	.691	.623	.659	.692	.652	.625	.724	.690	**.780**			
PO	4.241	.769	.899	.639	.704	.694	.645	.657	.658	.660	.630	.675	.711	.669	**.800**		
PR	3.973	.835	.890	.618	.679	.623	.647	.621	.652	.656	.553	.729	.676	.648	.613	**.786**	
ST	4.046	.792	.885	.658	.714	.647	.641	.647	.667	.663	.591	.696	.672	.672	.616	.773	**.811**
TEAM	4.278	.776	.907	.661	.701	.687	.630	.730	.736	.642	.650	.678	.758	.731	.704	.575	.614

other in Table 17.7. For the ESCI other analysis, the sample size exceeded available memory, so half of the sample was randomly chosen for this analysis. In the ESCI self, some items were dropped from to conform to desirable loadings. The specific items dropped for the ESCI self analysis included seven reverse-scored items (reverse-scored items for emotional self-control, coaching and mentoring, achievement orientation, inspirational leadership, teamwork, adaptability, and empathy). For this same analysis, six other items were dropped: one from emotional self-awareness, one from coaching and mentoring, one from adaptability, one from conflict management, and one from influence. Each of these items has been reworded to possibly correct for the loadings in the latest revision to the ESCI. For the ESCI other analysis, only one empathy item was dropped. For research purposes, a list of these specific items is available from the first author. No items had to be trimmed for the ESCI-U self or other.

Validity of the Behavioral Level with Coded Interviews

One form of assessment of the behavioral level of EI and SI is the critical incident interview, also known as the behavioral event interview (Flanagan 1954; Boyatzis 1982; Spencer and Spencer 1993). Work samples are collected and then coded by blind coders with high inter-rater reliability (Boyatzis 1998). Boyatzis (1982) provided the first published validation of these competencies against effectiveness measures in a sample of 253 managers and executives from six large private sector organizations and six large government organizations which included samples from the US Navy and Marine Corps. Although many studies followed in the 1980s and 1990s, these studies were often done by consultants and were not published.

A series of studies done in the 1990s were published later, showing the link between the use of the EI and SI competencies and work effectiveness using the critical incident interviews. Dreyfus (2008) showed that the EI and SI competencies predicted effectiveness of branch chiefs in research (middle-level managers) at NASA. Williams (2008) showed they predicted effectiveness of elementary, middle, and high school principals in a large urban city. Boyatzis and Ratti (2009) made the same links in samples from a large company in Italy and top executives from cooperatives also in Italy. Ryan et al. (2009) reported a significant prediction of effectiveness of the EI and SI competencies in executives in a variety of European companies. Gutierrez et al. (2012) showed the links to effectiveness of coded EI and SI competencies in top executives in India and China and compared them to comparable samples from Western Europe.

Another benefit of assessing EI and SI at the behavioral level is that it should be more amenable to change and improvement than other levels. To document change, EI and SI competencies were shown to significantly improve for four cohorts of full-time MBA and two cohorts of part-time MBA students as compared to two cohorts of each type of MBA in a baseline study in earlier years (Boyatzis et al. 2002) in the USA and in Italy (Camuffo et al. 2009).

Validity of the Behavioral Level with Early Versions of the ECI or ECI-U

Using a 360 or multisource assessment as a way to measure EI and SI in behavior—as seen by others—provides an easier assessment tool. It is less costly in human effort to collect and score and provides more of a consensual validation that improves face validity of the results. It is a test of the behavioral level of EI and SI.

Using a company-customized variation of the earlier version of the ESCI, called the SAQ/EAQ (Boyatzis 2009), Boyatzis (2006) conducted a tipping point analysis and showed the operating profit contribution of senior partners per year in a longitudinal study of executive performance in a major international consulting company. When senior partners used EI competencies above the tipping point (as seen by others), as compared to those senior partners showing the competencies below the tipping point, they showed 78 % high gross operating profit from their accounts for the EI cluster of self-management and 390 % increase for the EI cluster which they called self-regulation. In the same study, the increase in operating profit from senior partners above the tipping point (again, as seen by others) in SI competencies was 110 %. Even the operating profit contribution of senior partners was 50 % for those above the tipping point in demonstrated cognitive intelligence competencies.

Using the earlier version of the ESCI, called the ECI-2, Hopkins and Bilimoria (2008) showed that female bank executives showed that the use of the EI and SI competencies (as seen by others) was associated with higher measures of success in terms of the company's performance appraisal system. Koman and Wolff (2008) showed a similar pattern for US Navy Commanding Officers of flight crews when assessed against actual performance of the flight in combat simulations and air maneuvers. EI/SI as seen by others was significantly related to job performance at Johnson & Johnson in a study of 358 managers (Cavallo and Brienza 2002).

In another domain, Boyatzis et al. (2011) showed that Catholic Pastor priests who demonstrated more EI and SI competencies as seen by others working with them showed higher parishioner satisfaction on a complex measure of eight dimensions of parishioner involvement in the church and community. It did not predict church attendance nor donations per family.

In a study of Spanish nonprofit executives, Ramo et al. (2009) showed that using more EI and SI competencies predicted effectiveness. Camuffo et al. (2012) showed a similar set of findings for Italian executives from a variety of companies in Northern Italy. (Nel 2001; Aliaga and Taylor 2012) showed that using more EI and SI resulted in more effectiveness in Peruvian managers in a copper refinery. Sharma (20121) showed that Indian middle-level managers from large companies and public sector organizations who demonstrated more EI and SI than others were more effective. Sevinc (2001) reported EI/SI scores (as seen by others) were significantly correlated with salary, job, and life satisfaction of 71 Turkish professionals in the financial services sector. In South African call centers, the EI/Si as seen by others of 135 call agents was significantly related to job performance (Nel 2001). A study of 33 business development managers at Bass Brewers in the UK showed that EI/SI, as seen by others, was significantly predictive of a multidimensional measure of job performance (Lloyd 2001). All of these studies used the ECI-2.

Van Oosten (2013) showed that demonstrating more EI and SI competencies, as measured with the ECI-2, predicted performance of bank executives. Her findings suggested that certain of these competencies, the ones associated with leading change were the most effective. In a study of first responders, fire fighters and officers in London, Stagg and Gunter (2002) showed that EI/SI (again, as seen by others) was statistically related to a battery of performance measures.

In comparing performance against a traditional measure of academic cognitive intelligence, Victoroff and Boyatzis (2013) showed that assessment of the EI and SI competencies, as seen by other dental graduate students 6 weeks into their program, predicted their grades in the third and fourth year courses, which all take place in the dental clinic working with patients under faculty supervision. Meanwhile, the Dental Admissions Test (DAT) predicted grades in the first and second years of the graduate dental program which are all didactic courses, but showed no prediction of their grades in their third and fourth clinical years.

This result supports the finding of discriminant validity of EI/SI competencies with traditional measures of cognitive intelligence. Murensky (2000) studied 90 oil company executives and found no relationship between Watson-Glaser Test of Critical Thinking and the EI and SI competencies. She found three of the SI competencies to have a negative correlation to the Watson-Glaser. In Philippine plants of two multinationals, Sergio (2001) showed that others' assessments of 134 plant supervisors' EI/SI was significantly linked to job performance. A mental ability test was also linked to performance, but the mental ability test and EI/SI were not correlated. These studies support the idea that behavioral EI/SI is a different human capability or talent than cognitive intelligence.

Again, assessment at this level of EI and SI allows for careful studies of change. Boyatzis et al. (2002) reported on one cohort of graduating full-time MBAs with the SAQ/EAQ; Boyatzis and Saatcioglu (2008) were able to add another cohort of full-time MBAs using the SAQ/EAQ and two more cohorts using the ECI-U (the earlier version of the ESCI-U); and Boyatzis et al. (2010) added yet another cohort of full-time MBAs with the ECI-U showing dramatic improvement on the EI and SI competencies, as compared to baseline years and the MBAs themselves at entry into the program.

Validity of the Behavioral Level with the ESCI or ESCI-U

The ESCI and ESCI-U reflected several major improvements on the earlier versions of the test of EI and SI at the behavioral level. First launched in 2007, the validation research is just emerging. Studying the effectiveness of sales executives in a financial services company, Boyatzis et al. (2012) found that demonstrated EI and SI predicted effectiveness. They were able to assess cognitive intelligence using Ravens Progressive Matrices and personality using the NEO-PR and found that EI/SI competencies as seen by others predicted effectiveness, but cognitive g and personality did not. In addition, they were able to focus, through multiple regressions, on the fact that adaptability was the most powerful predictor of leader effectiveness among the EI competencies and influence was among the SI competencies.

In a study of leaders from a variety of companies, Havers (2010) showed "leaders who demonstrated fewer than three ESCI strengths drew upon a limited range of leadership styles, tending to rely primarily on the coercive style … In contrast, leaders with 10 or more ESCI strengths used a much wider range of leadership styles, including those likely to engage their team members, providing long term direction and vision, creating harmony, encouraging new ideas and investing in others development" (p. 2). Furthermore, Havers (2010) reported that 92 % of the leaders showing high emotional self-awareness created a positive organizational climate (as seen by their subordinates), while 78 % of the leaders with low emotional self-awareness created a negative climate.

Also in the sales function, Lisicki (2011) showed that EI and SI competencies predicted sales performance of sales people in a pharmaceutical company. He showed that coaching and mentoring competency was the most potent factor in predicting sales performance.

A leader's EI and SI, as assessed with the ESCI, is associated with their subordinates' job performance and satisfaction in a study of 20 leaders form a multinational in Egypt (Shams 2008). She found that subordinates' job satisfaction was significantly correlated with all of the EI competencies and four of the seven SI competencies. Meanwhile, subordinates' job performance was correlated with emotional self-awareness and emotional self-control from the EI cluster and influence from the SI cluster.

In a sample of Indian managers, Badri (2013) showed that EI and SI competencies as seen by others assessed with the ESCI predicted leader effectiveness and use of the transformational leadership style. He found a relationship to transactional leadership style as well, but only for one subscale, and others were negatively related to use of EI and SI. This supported the findings of Piel (2008) in a study of 82 project managers from various companies that EI and SI, as assessed with the ESCI, was related to using the transformational leadership style.

Using the self-assessment from the ESCI, Quinn (2013) showed that it predicted physician leader effectiveness in terms of participation as a leader in hospitals. Pittenger (2012) showed that for IT managers and advanced professionals from a variety of companies, EI and SI competencies predicted effectiveness in terms of engagement.

Using a 360 from their own competency model of EI and SI, Young and Dulewicz (2009) showed the same pattern found earlier with the US Navy in that EI and SI as seen by others predicted leader effectiveness for British Naval officers. Ryan et al. (2012) showed that EI and SI with a 360 from a customized competency assessment in a large Swiss company predicted executive effectiveness.

Conclusion

The behavioral level does provide theoretical and empirical support for the relevance of EI and SI in predicting effectiveness and work and life outcomes. It also shows that at least one measure of the behavioral level, the ESCI or ESCI-U, satisfies appropriate psychometric standards of a reliable and valid test, with appropriate convergent and discriminant validity, and is a good model fit for each of the separate scales.

This explanation of the levels of EI may serve to refocus the intellectual debate on the conditions when the relationship of EI (and SI) helps us to understand performance, effectiveness, and life and job outcomes. It offers a theoretical rationale as to how the three approaches to EI do function in unison within the person. But the different levels require different types of measurement. This is where the ESCI can complement the MSCEIT and EQ-i in research.

Practical implications of the behavioral level are considerable. It is far easier to document improvement on the behavioral level than other levels as has been shown in published research. The behavioral level guides coaches and trainers seeking to improve performance of executives, managers, and leaders, along with professionals in organizations. It can be a guide and tool for graduate and undergraduate programs seeking to develop the whole person, not just their knowledge, and help such academic programs with the needed outcome assessment for accreditation and documentation of program impact.

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Intelligence as a Malleable Construct

18

Lisa S. Blackwell, Sylvia Rodriguez, and Belén Guerra-Carrillo

Introduction

The academic debate about the nature of intelligence resonates broadly not only with educational practitioners and policy makers but also with the general public. Most people think they know what intelligence is and that they know it when they see it. But what do people mean when they talk about being smart, brilliant, or clever? And why does it matter so much?

In this chapter, we focus on research showing how the way that people think about intellectual ability drives the choices they make and the outcomes they achieve, sometimes in counterintuitive ways. We show how a person's concept of intelligence can impact both their performance on cognitive tasks in the short run and their achievement over the longer term, and why this is so. We review the evidence from cognitive neuroscience for these different conceptions of intelligence. Finally, we discuss how such concepts can be influenced and changed and the practical implications of this research for educational policy and practice.

Why do people care so much about the nature of intelligence? Traditionally, particularly in western cultures, intelligence has been seen as the golden ticket to success. If you had a good amount of it, you would be rewarded with educational, professional, and financial success, and those with a great deal—the geniuses among us—would attain eminence and make a mark on posterity. Implicit in this view is the idea that intelligence is a "gift"—an innate attribute that one possesses in a relatively fixed quantity, for better or worse. Historically, the relatively high stability in individual performance on intellectual assessments over time and across tasks has led many to assume that this view of intelligence as fixed is correct (see, e.g., Bartels et al. 2002; Canivez and Watkins 1998; Herrnstein and Murray 1994; Hertzog and Schaie 1986), despite the strong dissent of original developers of the first IQ test, Alfred Binet and Theodore Simon (Binet 1975; Wolf 1973).

Unfortunately, in this case, believing may make it so. Because our society has presumed that intellectual gifts are innate and could be measured accurately, our education system has traditionally been structured to identify those students with apparent above-average intelligence, enrich their instruction, and track them into ever-greater opportunities, while those with presumed below-average ability were channeled into programs that

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would prepare them for lower-skilled jobs (Borland 2003, 2005; Borland and Wright 2001; Darling-Hammond 1994, 1995; Kaufman 2013; Nisbett 2009). The result is that those who score well on performance measures early on are in fact generally offered more opportunities to cultivate their intellectual ability than those who do not and, at least partly as a result, often do become more skilled and successful, reinforcing our common paradigm of innate ability.

It turns out that something similar happens in the psychology of the individual as well. Our research, and that of many colleagues, shows that people's "theory" of intelligence—whether they believe it to be fixed or a malleable quality—influences the learning opportunities they will pursue, the effort they will invest, and their resulting growth. It can even impact how their brains function.

Mindsets About Intelligence

In a ***fixed mindset*** (often referred to as an ***entity theory*** in the research literature), people believe that their intelligence is relatively fixed, and there is not much that they can do to develop it. They agree with statements such as "you can learn new things, but you cannot really change your basic amount of intelligence." In contrast, in a ***growth mindset*** (also known as an ***incremental theory***), people believe that their intelligence is something they can change and develop incrementally over time. They agree with statements such as "you can always greatly change how intelligent you are" (Dweck 1999). As we will show, these different mindsets about intelligence drive the goals that people hold, the challenges they will tackle, the effort they will expend, their persistence in the face of difficulty, and, as a result, their performance and achievement over time (Blackwell et al. 2007; Dweck 1999; Dweck and Leggett 1988; Henderson and Dweck 1990).

Mindsets and Motivation

Over the past few decades, a wealth of research shows that, even when people demonstrate equal intellectual ability and skill, their beliefs about intelligence shape their responses to intellectual challenge. For those who hold a fixed mindset, the conception of intelligence as a fixed, uncontrollable quantity (of which they may have a lot or a little) orients them toward measuring and obtaining a positive evaluation of their ability. Thus, their primary goal is usually to perform well in order to appear smart—or at least to avoid performing poorly and looking dumb (Blackwell et al. 2007; Dweck and Leggett 1988). They tend to think that things come easily if one is smart and that effort is both a sign of low ability and relatively ineffective in overcoming it (e.g., Blackwell et al. 2007; Hong et al. 1999). When they experience a setback or failure, they are likely to attribute it to low ability rather than effort (e.g., Henderson and Dweck 1990), doubt their ability to recover, and manifest a "helpless" response, withdrawing effort and giving up rather than risking further exposure as unintelligent or untalented (e.g., Robins and Pals 2002).

On the other hand, those who hold a growth mindset, in which intelligence is a malleable quality that can be cultivated, are more focused on learning (thus increasing their ability) as a goal, even if it requires effort, struggle, and errors along the way (Dweck 1999; Dweck and Leggett 1988). They consider effort to be a pathway to development (e.g., Hong et al. 1999), and when they experience setbacks, they attribute them to lack of sufficient effort and in turn adopt a mastery-oriented approach, increasing their effort and taking on new study strategies (e.g., Robins and Pals 2002).

Thus, the different mindsets about intelligence set up different frameworks or "meaning systems" (Hong et al. 1999) for interpreting situations that involve learning, effort, challenge, and evaluation. Furthermore, it is when making a transition to a situation that poses ongoing, increasing challenge (where success is more difficult and less certain) that these mindsets have the greatest impact on behavior and achievement.

In a comprehensive longitudinal study with urban, largely minority students, we examined how students' mindsets set up contrasting motivational frameworks and academic outcomes as they made their way through a challenging transition to junior high school (Blackwell et al. 2007).

We studied three waves of students over three successive years, assessing their mindsets at the beginning of their seventh grade year and then following each wave as they made their way through the following two years of school. First, we examined how their mindsets were related to their goals in school, their attitudes toward effort, and their responses to failure. Analyses showed that, as found in prior studies, students with a growth mindset had stronger learning goals than the fixed mindset students—for example, they said that "It's much more important for me to learn things in my classes than it is to get the best grades"—and had much more positive attitudes toward effort, agreeing that "when something is hard, it just makes me want to work more on it, not less." Students with a fixed mindset, on the other hand, were more likely to say that "If you're not good at a subject, working hard won't make you good at it," and "When I work hard at something, it makes me feel like I'm not very smart."

How did these two groups of students feel about failure? These mindsets, goals, and beliefs about effort in turn predicted how students said they would respond to a poor grade on a quiz: the growth mindset students showed a clear mastery-oriented response, saying that they would "work harder in this class from now on" and "would spend more time studying for the next test." In contrast, many of the students with a fixed mindset had a helpless response—for example, saying they would "spend less time on this subject from now on," with some even admitting that they "would try to cheat on the next test" rather than risk another failure!

Mindsets and Achievement

How did these different mindset frameworks impact achievement over this challenging transition? Based on their prior sixth grade test scores, when they were in the less-challenging elementary school environment, the fixed and growth mindset students had similar levels of math skills upon entry into junior high school. But by the end of the first term, they began to pull apart, with the growth mindset students performing better, and these diverging trajectories continued over the next two years, widening the gap between the two groups each term (Fig. 18.1).

We examined the pathway from mindset to achievement outcomes using hierarchical linear modeling and found that the beliefs, goals, and attitudes that led to different patterns of behavior were responsible for the diverging trajectories of grades. The increasing challenge level, particularly in the math curriculum of a health science-focused school, spurred the students with a growth mindset to focus on learning, work harder, and use positive strategies when they encountered difficulty, with the result that they mastered the curriculum better than those who entered with a fixed mindset, despite the fact that both groups began with similar skills (Fig. 18.2).

What do these mindsets sound like in the words of real students? A rising eighth grader with a growth mindset explained how he thought about intelligence as a product of one's choices and behaviors, inextricably tied to learning and effort:

> Well, you can change it [your intelligence] because people are different. One year they can be lazy in school and the other year they're like, "All right, I've got to step it up because I want to get into college." … What makes me feel smart is participating and doing my homework and everything, because then I know that I'm doing my best.

Asked whether he liked schoolwork that made him think hard, he emphasized the value of challenge to his growth:

> Yes, I do, because it gives me a challenge and also it'll help me a lot and I can do better with it and everything.

Contemplating the prospect of failing a test, he immediately began seeking solutions based on effort:

> I would feel really bad, but at the same time I wouldn't be surprised because maybe the year before that you did really good, and then you know like you just put that same amount of effort. But like that year, the new year, it gets harder and everything… Maybe there was some notes that you could write down but you didn't bother because you already knew them. Maybe you didn't have it all memorized, so you forget some of the stuff. I guess what I would do was maybe work harder,

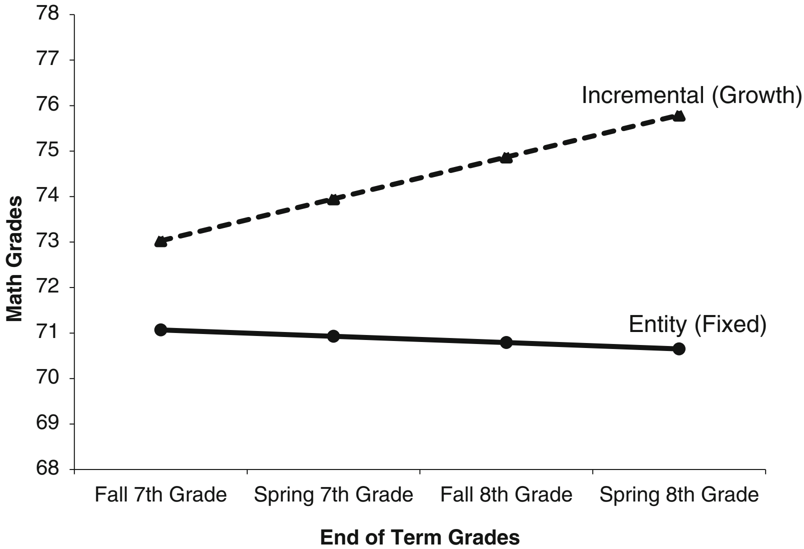

Fig. 18.1 Trajectory of middle school achievement as a function of student mindset in Study 1 (Notes: Growth and fixed mindset groups entered seventh grade with equal math achievement based on sixth grade test scores (not shown). They began to diverge by the end of the fall term of seventh grade (mid-year). By the end of eighth grade, the achievement gap was 10 % of the total grade points that differentiate a failing grade (60 %) from a perfect score (100 %). Reprinted from Blackwell et al. 2007, p. 251. Reprinted with permission. Copyright 2007 from Society for Research in Child Development, Inc.)

> and start thinking, Oh, wow. Okay, so I didn't do so good but maybe this time I can do good.

In contrast, his classmate laboring under a fixed mindset talked about her uncertainty about her ability to learn and how it made her feel helpless:

> Well I'm going to have to probably agree [that you can't change your intelligence] because sometimes– well for me there's limits on what I can learn and what I can't… I tend to space out a lot. And when I space out it's like the teacher will ask me a question and I have no idea what she's saying. And so I just have to sit in silence until she gives up and picks somebody else.

When asked what made her feel smart, she looked to external validation through getting the "right answer" and admitted that she preferred things she could do easily versus challenging work:

> Like say I got a question right in front of the whole class, then that makes me feel like kind of smart and special … I think it's so much easier and quicker if you know it by heart and you just do it right away and get it over with … Over-thinking sometimes can just really frustrate me. What I've done is I would just give up and my friends would sometimes give the answers to me.

When contemplating failure, she shared a recent incident and her collapse in the face of challenge:

> I was doing my test and what happened is I was reading this question that I really didn't know … from there on I just circled randomly and I just completely gave up on them, even like trying on the test.

The motivational implications of these two different frameworks, and their resulting impact on performance and achievement, have been demonstrated in many studies spanning kindergarten through graduate school (Aronson et al. 2002; Blackwell et al. 2007; Dweck and Leggett 1998; Good et al. 2003; Heyman et al. 2003; Kray and Haselhuhn 2007; Smiley and Dweck 1994; Yeager et al. 2013). Over and over again, researchers have shown that the way people think about their intelligence can become a self-fulfilling prophecy, expanding or limiting their motivation, growth, achievement, and, ultimately, their ability.

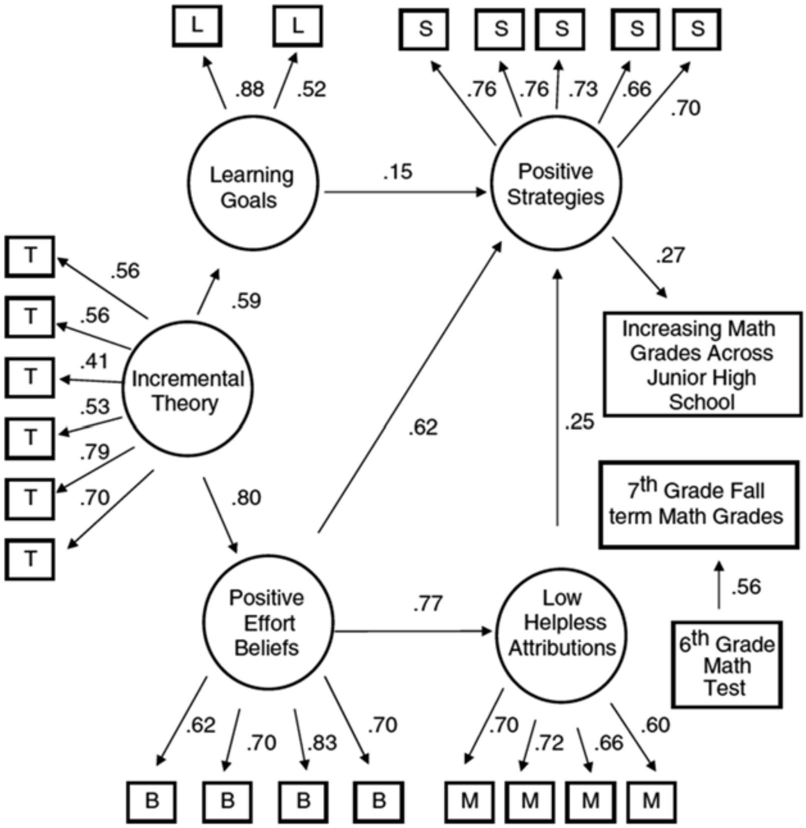

Fig. 18.2 Process model depicting the relations between student mindset, other beliefs and behaviors, and achievement in Study 1 (Notes: The more firmly students held a growth mindset (incremental theory), the more they endorsed learning goals and positive beliefs about effort. These goals and beliefs were associated with positive learning strategies and resilient responses to challenge, which in turn predicted greater math achievement gains. Reprinted from Blackwell et al. 2007, p. 253. Reprinted with permission. Copyright 2007 from Society for Research in Child Development, Inc.)

How Malleable Is Intelligence Really?

Without doubt, people can gain knowledge and skills through learning, but can they really develop their intelligence as we understand it? A robust debate about the true nature of intelligence continues (see, e.g., Kaufman 2013; Nisbett 2009), but most people think of intelligence as a generalized capacity for learning and reasoning that can be assessed by instruments such as IQ tests. Without weighing in on that complex question, we can agree that the version of intelligence measured by standard IQ tests is the result of combining scores from various subtests that measure a wide variety of knowledge and cognitive processes that are highly intercorrelated, such that if you score well on one, chances are that you will also score well on another. James Flynn (2007) explained this calculation with a clever analogy comparing it to measuring performance in a decathlon, where performance is computed from 10 events that each assess a different ability. For example, strength can be calculated from performance on throwing events, while speed can be assessed through sprinting events. Similarly, different subtests of intelligence assessments measure cognitive factors such as our ability to maintain and manipulate information in mind (working memory), integrate features of and consider relationships between stimuli (reasoning), and process information fluidly (processing speed), among others. A portion of these subtests may also measure the accumulation of knowledge about the meaning of words or arithmetic rules (Naglieri and Goldstein 2009). Intuitively, one can suspect that what we do or are exposed to in our daily life could influence how well we score on one or many of these different subtests and subsequently affect how *intelligent* we are deemed to be. However, for a long time, it was believed that intelligence was something we inherited and could not do much to change (see, e.g., Herrnstein and Murray 1994).

The evidence for the primacy of innate ability has not been well supported by accounts measuring population changes in IQ performance since the inception of the Weschsler Intelligence Scale, one of the main measures of intelligence. The well-documented Flynn effect (Flynn 2007) describes how IQ scores on multiple well-established assessments of intelligence have been on the rise—in some instances, dramatically—from generation to generation, even on assessments that are deemed to be largely "culture-free." A compelling interpretation is that the performance capacities measured by these tests function as skills that can be improved and shaped by experience and schooling and that these experiences have shifted over time in a way that has changed how and what is learned by the majority of the population (Flynn 2007; Nisbett 2009).

In fact, over the past century, various studies conducted all over the world have documented the role that schooling plays in cultivating students' intelligence. If intelligence is a fixed ability, environmental experiences, such as educational enrichment, should not alter it. Yet, countless examples confirm the finding that, relative to children who remain in school, those who are denied educational experiences often display a gradual but persistent decline in performance on intelligence measures—as much as 6 IQ point decrements for every year of schooling lost (see Ceci 1991; Nisbett 2009 for a review). Similarly, related environmental factors such as socioeconomic status have been found to predict individual change in IQ, with low-SES children showing a decrease in IQ over time (Breslau et al. 2001).

To what extent are scores on assessments of these sorts malleable, and how does experience and learning impact performance on them? Over the last few years, research aimed at answering this question has provided strong evidence suggesting that cognitive skills such as those tested by intelligence tests can in fact improve with practice.

In one study, elementary school children at a low SES school played with one of two sets of board games and video games for 8 weeks (Mackey et al. 2011). In the first group, children played with games that engaged their reasoning ability, such as games that asked them to consider and integrate multiple rules or complete patterns of shapes. A second group of children played with games that involved processing speed, which required them to make motor responses to visual cues as fast as possible following simple game rules. At the beginning and again at the end of the 8 weeks, tests in relevant areas pertaining to either reasoning ability or processing speed were administered. The results were striking. Children who had played with the reasoning games increased their nonverbal reasoning by 32 %, which translates roughly to a 10-point increase in IQ. On the other hand, those who had played with the processing speed-focused games increased their processing speed by 27 %, but not their reasoning skills. These results demonstrate not only that IQ scores can change significantly in a short period of time but, more importantly, that targeted interventions can improve performance on the cognitive processes assessed in intelligence measures, contradicting the belief that our intelligence is fixed.

Studies examining other cognitive functions measured by intelligence tests have shown converging evidence that speaks to the malleability of these constructs. For example, Brehmer et al. (2012) asked a group of adults to use an adaptive computerized program to train working memory and compared them to a control group that used a nonadaptive, low difficulty working memory training. Before and after the training period, participants completed assessments of working

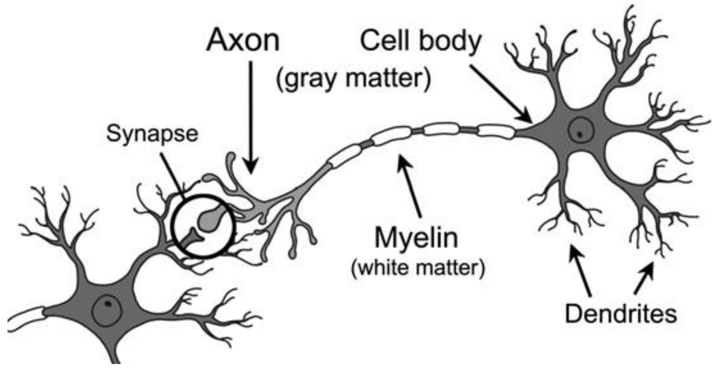

Fig. 18.3 Illustration of neuron with connections (Copyright 2013 from Mindset Works, Inc.)

memory, which were the same as those administered as part of the Weschsler Intelligence Scale. As part of the training, participants practiced maintaining in mind over short periods of time multiple bits of information (words or locations of objects in space). They also sequenced these items in a particular order according to the exercise's instructions. For those in the adaptive training program, the quantity of information that needed to be held or manipulated in working memory changed depending on their performance, increasing (and therefore becoming more difficult) as participants became more proficient. After five weeks of training, participants in this adaptive training group showed significant improvements in their working memory performance. These improvements were greater compared to the group that did not receive an adaptive training, even though both groups began their training with similar scores. Interestingly, in a follow-up assessment, researchers found that the performance gains made by the adaptive training group were maintained three months after the training period. These findings are especially impressive given the brief nature of the intervention.

In sum, these examples support the idea that the cognitive skills measured in intelligence tests can be improved and maintained by targeted training using increasing demands (challenge). The significance of the flexibility of these cognitive functions extends beyond improvements in a test score—they speak to our capacity to continue to adapt to new cognitive demands imposed by our environment.

Neuroplasticity and Brain Function

How do learning-based gains in cognitive performance relate to the modifiability of neural structures in the brain? Research in the neuroscience of learning demonstrates significant plasticity in brain structure and function and shows that these changes are highly dependent on both behavior and environment.

The brain is composed of billions of specialized cells known as neurons (see Fig. 18.3). Neurons form part of the body's communication hub, processing, sending, and receiving vital information through an interconnected network. Surrounding a neuron's center are a series of extending branches known as dendrites that oversee and transport the collection of chemical messages received from other neurons. Collected information is eventually converted into an electrical impulse that travels down a long channel known as the neuron's axon. This axon branches out into smaller axon channels that each culminate in a small bulb that forms part of a structure called a synapse. It is at a synapse where the impulse triggers the release of chemical substances, or neurotransmitters, from the neuron. These neurotransmitters then enter the receiving neuron through receptors of the receiving neuron.

Although brain plasticity may not be specific to neural changes, much of the research has focused on how the connectivity between neurons can change with experience. Studies on animals have informed us about the changes that occur at a cellular level that may modify the connection of neurons within and between brain regions. Based on those findings, Zatorre et al. (2012) discuss some of the changes that may happen at the cellular level and underlie plasticity in the human brain. For example, axons can become insulated with myelin, a fatty tissue that makes up the "white matter" of the brain and speeds the transmission of electrical impulses, or their existing myelin covering can become thicker. Also, groups of axons projecting between brain regions can become more organized, thus improving their connectivity. In humans, one or many of these transformations may reflect changes in the integrity of the microstructure of the brain's white matter, which contains groups of myelinated axons whose cell bodies form the brain's gray matter. In addition to speeding up their transmission, neurons can improve their connectivity by increasing their surface area of connections through the creation of new neurons and synapses or branching of dendrites. These events may be reflected in the structural and functional changes of the gray matter after repeated practice of a physical or mental skill.

An example of our brain's ability to adapt to slight modifications to our daily activities can be seen in a seminal study where a group of individuals with no juggling experience were taught how to juggle over a period of three months. In comparison to their own brain scans taken at the beginning of the study and also to those of a group of individuals who were not taught how to juggle, the post-training brain scans of the jugglers showed an increase in the gray matter thickness of brain regions that support the ability to perceive motion and anticipate where objects will be in space (Draganski et al. 2004).

Changes in the brain are not limited to developing a new visual-motor skill. Exciting findings from studies where participants practiced a cognitive process have revealed the brain's ability to adapt to different cognitive demands. Using functional magnetic resonance imaging (fMRI), which measures changes in blood oxygenation and flow in the brain associated with neural activity, Mackey et al. (2013) measured the neural effects of intensive reasoning training in young adults. After a three-month law school admission exam (LSAT) preparation course, in which a little over 60 h were devoted to practicing problems that relied heavily on reasoning, the fMRI scans showed changes in the intrinsic connectivity of the student's brains. The measure of intrinsic connectivity, known as resting-state fMRI, is thought to reflect repeated history of synchronized activity between regions, since the scan is captured at resting state, when a person is asked not to engage in any task. The group of individuals who underwent the reasoning training showed greater intrinsic connectivity between areas involved in reasoning skills compared to their well-matched controls, and a specific pattern of these connections was related to greater improvements in their LSAT scores.

In addition, these researchers also examined the changes in white matter microstructure resulting from this training program (Mackey et al. 2012). They found an increase in the coherence of white matter tracts connecting regions of the brain that support reasoning skills, reflecting the integrity of the structure of white matter discussed earlier. Although the specific mechanisms behind these changes are unknown, they are, nonetheless, thought to reflect strengthening of the connectivity between brain regions brought on by experience or development.

The brain's malleability also makes it susceptible to negative factors, such as stress or unstable home environments (see, e.g., Erikson et al. 2003; Hackman and Farah 2009; Lupien et al. 2009). To counteract this, Neville and colleagues (2013) developed an 8-week intervention targeting selective attention, the ability to control where our focus is directed, in part aimed at increasing school readiness for preschoolers of low socioeconomic status. They reasoned that because a stressful environment and more inconsistent parenting practices are often more prevalent in low-SES compared to higher-SES households, training preschoolers' primary caregivers might also be beneficial. Thus, they compared three groups of children. One received their preschool education as usual. A second group received attention exercises only. A third group of children also received attention exercises, and their parents received training in a curriculum targeted to develop family stress regulation and other strategies aimed at improving the way parents interacted with, disciplined, and facilitated their children's attention. To explore the impact of the training on cognitive functioning, researchers used electroencephalography (EEG)—a noninvasive measure with excellent temporal sensitivity that can be used to capture changes in electrical potentials occurring within the brain that are elicited from the scalp. The signal embedded in this EEG, known as event-related potentials (ERPs), can map out attentional and conceptual processes that emerge in response to specific task-related events, such as hearing a particular sound. In a test where children were asked to focus their attention on only one of two stories played simultaneously, early attention ERP components related to probes embedded in the stories showed that children who received the family-based intervention were more successful at focusing their attention on the story they were instructed to attend. Additionally, this group also improved in measures of nonverbal IQ, while their parents showed lower levels of stress.

Together, these studies suggest that experience and learning can result in tangible, measurable impacts on the brain and in turn on a variety of cognitive functions. This is especially promising because these brain changes are seen in response to small changes in the experiences a person engages with, such as practicing a specific skill over a short period of time. Given these findings, we can anticipate that, as they continue to work and study, virtually all students can continue to develop their abilities over time through positive behaviors like effort and practice, in a way that would ultimately be evidenced by changes to brain structures and activity.

The evidence of performance improvement and neuroplasticity seen in these studies lends support to the concept of malleable intelligence that underlies a growth mindset. Further, the fact that such changes are the result of behaviors such as deliberate practice and engaging with increasingly difficult tasks helps illuminate why the increased effort, challenge seeking, and persistence associated with a growth mindset would result in higher achievement. Intelligence can be developed—but only if it is exercised. But our colleagues and we wondered whether engaging in overt behaviors, such as practicing and tackling more challenging tasks, were the only way that mindsets could impact learning—or whether the beliefs and goals that make up the different mindsets might directly influence the way the brain processes information.

The Neuroscience of Mindsets

What is happening in the brain when people are laboring under the different mindsets? Researchers have begun to explore some of the neural mechanisms underlying a growth and fixed mindset.

A fascinating series of studies looking at brain activity in relation to mindset and different performance conditions showed that mindsets can lead to different patterns of observed activity in the brain, with consequences for cognitive functioning. Moser et al. (2011), for example, tracked how students allocated their attention while completing a task that required continuous monitoring and responding to a target displayed on a computer screen. How did students with different mindsets react, especially after making a mistake? To explore this question, researchers looked at specific ERPs that have been previously mapped to attention and awareness to errors. They found that individuals with a growth mindset were more likely to attend to the errors they made than those with a fixed mindset and were also more likely to improve their accuracy on the next trial.

Interestingly, additional analyses revealed that their attentional response mediated their performance. In other words, it was *because* participants with a growth mindset oriented their attention to errors that they did better on the task. These findings showed that people with a growth mindset were more successful at reorienting their attention to the task at hand and suggest that they were not discouraged by errors but responded in an adaptive way that allowed them to persist and improve.

Individuals with a fixed mindset may also orient attention to errors when there is salient negative feedback, but may do so in a way that ultimately undermines learning (Mangels et al.

2006). An ERP study by Jennifer Mangels and her colleagues found that individuals with a fixed mindset showed an enhanced awareness of and orientation towards errors made on a challenging general knowledge question task, in which individuals received accuracy feedback (whether their response was correct or incorrect) followed by learning feedback (the correct answer) after each question. However, unlike the growth mindset group in the previous study, this orienting did not aid their performance. Fixed mindset participants showed a neural response to learning feedback that was indicative of lower success at encoding the correct answer or storing and committing the information to memory. In fact, in a surprise retest of all the items that they had previously answered incorrectly, fixed mindset participants corrected fewer items than their growth mindset counterparts.

These findings illustrate how people's mindsets may differentially impact their attentional response, particularly following challenge. On one hand, individuals harboring fixed mindset thinking may inadvertently set themselves up for failure by directing their attention to their performance and discounting an opportunity to learn from their mistakes, whereas this does not seem to be the case for those with a growth mindset.

As previously discussed, students with a fixed mindset often hold a performance focus in which they are particularly concerned with the goal of proving their abilities and achieving highly, especially in comparison to others, whereas those with a growth mindset typically endorse goals of learning and mastery (Blackwell et al. 2007; Dweck and Leggett 1988; Dweck 1999). What happens when students find themselves in academic contexts that promote either a performance or mastery goal? As students navigate from one academic context to the other, it is very possible that they may be receiving different messages from their environment about what is valued in each domain, potentially impacting how and what they learn.

In support of this possibility, recent ERP research finds that students do indeed have very different neural experiences when they encounter a mastery- versus performance-based context (Rodriguez et al. 2014). We recruited undergraduates to complete a challenging general knowledge task drawn from Mangels et al. (2006). The task, which contained two blocks of questions, prompted students to complete all questions in a block before being presented with the second block. Importantly, as students were presented with a block, they first read task instructions that differentially framed it. In the *performance* frame, students read instructions that oriented their focus on their accuracy and how their performance would be compared to that of other university students. However, in the *mastery* frame, these same students were instead asked to focus on those questions that they found most interesting and learned the best from rather than on their performance. How would students respond to these two different but comparably challenging situations?

When task instructions emphasized performance and proving one's ability relative to others, students completing the difficult task displayed a neural response to corrective information (i.e., the correct answer) following an error that was consistent with processes related to superficial encoding of that information. However, these very same students, when completing a task that instead emphasized learning and mastery, experienced a neural response to the correct answer (after an error) that was consistent with processes that reflect deeper encoding of that information.

This work suggests that although learning may occur in both mastery- and performance-based contexts, the nature of that learning may be very different. In a performance environment, students may attend to problem solving only insofar as it allows them to get the right answer, understanding it only at its surface, whereas in a learning environment, students may not be solely focused on their outcomes and instead orient their efforts to understanding the content in a manner that may ultimately contribute to longer-term retention. These findings are especially intriguing since these different neural processes, which are suggestive of qualitatively different kinds of learning, emerged within person after just brief exposures to each frame. Thus, they provide continued support for students' sensitivity and differential response to input from their learning environment. As we will see, messages conveyed to students through their interpersonal experiences with others can also powerfully shape their beliefs and behaviors in both the short and long term.

Mindsets and the Influence of Others

As we have seen, the mindsets that individuals carry with them affect their goals, cognitive functioning, motivation-related behavior, and academic outcomes. However, these mindsets themselves are not fixed. The messages that people get from others in their environment can influence their mindsets and impact motivation and performance in immediate, powerful, and often surprising ways. In fact, it turns out that the very messages that one might think would be most encouraging—such as praise for intelligence—can actually undermine performance on intellectual tasks.

A pioneering series of studies by Claudia Mueller and Carol Dweck (1998) examined the impact of praise on fifth graders' challenge seeking and performance. Mueller and Dweck had the children complete a set of puzzles drawn from Raven's Progressive Matrices (a common measure of nonverbal reasoning). Initially, they gave them problems matched to their grade level and children solved most of them successfully. Then the researchers praised the students for their performance. They told one group of randomly chosen children, "Wow, that's a really good score. You must be smart at this" (***intelligence praise*** condition). A second group was told, "Wow, that's a really good score. You must have worked hard at this" (***effort/process praise*** condition). (Process praise can refer to anything about the process the child engaged in: their strategy, focus, effort, choices, or perseverance.) Then they looked at how these different kinds of praise would affect the students' behavior and performance. First, they asked them which type of puzzle they would prefer to do next: an easy one, like the ones they had done, on which they would perform well, or more difficult ones, from which they would learn. While the children praised for process overwhelmingly chose the more difficult ones, the majority of children praised for intelligence chose to repeat the same easy puzzles! Rather than giving children the confidence to tackle a challenge, praise for intelligence had actually made them want to stay in their safe zone, even though it meant that they would learn nothing new.

Clearly, over the longer term, sacrificing such learning opportunities could have a negative impact on skill development. But strikingly, the praise also had an immediate effect on the children's intellectual performance. To test the impact of praise on the children's performance and resilience following challenge, the researchers next had the students work on more difficult puzzles, on which all the students struggled. They then gave them another easier set, similar to the first. How would they perform? The differences were telling. The students praised for effort improved significantly on the easy puzzles over their performance on the first trial (perhaps honing their skills on the more difficult problems). But those who had been praised for intelligence performed *worse* on the second attempt—they had lost confidence that they were smart at puzzles, and so they performed poorly. It is particularly notable that the Raven's task is one used to measure "fluid" intelligence (often considered to be an inherent problem-solving ability) and has often been used to assign children to gifted programs, yet it turned out that performance on this test could be undermined (or enhanced) by a single sentence. Intelligence praise activated a fixed mindset framework, along with the goals of looking smart and succeeding without effort, and produced a "helpless" response to challenge and an immediate decrease in apparent ability.

More recent studies have replicated and extended these findings. For example, one study explored how feedback linking success on an upcoming challenging activity to a group's supposed inherent ability impacted kids' performance on that task (Cimpian et al. 2012). The researchers found that when young (4–7-year-old) children were told that either girls or boys were really good at a game, the children, regardless of their gender, underperformed on the game, especially on more difficult items, relative to children who were provided with other kinds of instructions that did not suggest the inherent ability of groups. Cimpian and his colleagues argue that this occurred because children came to attribute their performance on the task as being innately linked to something out of their control—a "fixed" aspect of their identity, which in turn led to their underperformance.

Since the Mueller and Dweck (1998) studies, other researchers have investigated the impact of praise in real-world contexts on mindsets and performance over longer periods of time. They have found that parents can play a significant role in formulating their children's beliefs about their ability, sometimes with long-term effects. One longitudinal study found that children whose mothers gave them more process praise at 14–38 months were more likely to display a growth mindset and a greater desire for challenge at 7–8 years old (Gunderson et al. 2013). In a similar study with older children, 8–12-year-olds whose mothers praised them for ability were more likely to exhibit fixed mindset thinking and a reduced desire for challenge six months later (Pomerantz and Kemper 2013).

As the praise studies suggest, teachers too are in a position to influence their students' mindsets. For example, just as praise for intelligence can backfire, the way that we console children when they struggle may inadvertently trigger the fixed mindset pattern. Aneeta Rattan and her colleagues (Rattan et al. 2012) asked adults (some of whom were math teachers) to imagine a student in their class who had gotten a poor grade on the first math test of the year and to report how they would respond to the student. The adults in a fixed mindset were significantly more likely to try to console the student by saying that not everyone could be good in math—a message that students reported would lead them to conclude that they have low ability and to feel like giving up. However, adults in a growth mindset were more likely to urge students to try harder, and they gave them practical recommendations for strategies to achieve mastery.

In these ways, the mindsets that adults hold can be a factor in students' success. Indeed, a study looking at the impact of teacher mindsets on student achievement found that when teachers had a fixed mindset, students who had entered their class as low achievers remained so. In contrast, when teachers had a growth mindset, many of the students who had started the year as low achievers showed remarkable progress (Rheinberg et al. 2000). Thus, for the fixed mindset teachers, their experience confirmed their beliefs, as their students' relative status remained unchanged, whereas the growth mindset teachers saw their confidence in students' ability to grow realized. Once again, the mindsets that people hold can become self-reinforcing.

Crucially, a growth mindset is not the same as self-confidence or drive to achieve. In fact, as we saw in the praise studies, successful students who derive much of their self-esteem from performing well can be vulnerable when they encounter challenge or difficulty—particularly if they are in an evaluative context. Here, a young student about to begin middle school seems to have a robust sense of self-confidence as he explains his relish for a challenge—but his primary goal is to demonstrate his ability, rather than to learn:

> Right now my favorite subject is math because I'm really good at it – my grades in my report card have been really high in math so that's why I like it … A lot of times kids don't really want to work hard. But if you really want to know something new and really get good at it, you're going to have to work hard. And some kids like working hard. So it's like a challenge, like a puzzle… I like doing stuff that I'm good at and I know I'll get a good grade. And then I like thinking because I like – I'm the type of guy that likes puzzles and I like challenges 'cause it makes you feel like you're up to it and you're showing the person what you can do and it makes you feel good.

This student enjoys a challenge, as long as he can be successful. But in a situation where he may make mistakes in class and lose his status as a top performer in the eyes of others, his motivation takes a nosedive:

> If you're doing it [making mistakes] in front of people? I wouldn't really want to do it because when you make a mistake you kind of tend to get embarrassed and people will say, "No, you're doing it wrong. What are you doing?" and that tends to be

> embarrassing … Like if you're doing a group and there's tons of kids around you, when you ask for help then they know you're not understanding it. And then some people say that's really easy and they're like, "How are you not understanding it?" It makes you feel stupid, and then you get embarrassed.

Thus, as we saw in both the study of students making the transition to junior high school and in the praise studies, a fixed mindset framework may not hurt performance in conditions of relatively low challenge, where students' skills exceed the demands of the task and success is readily obtainable. But when the possibility of failure looms in a situation where ability may be evaluated, mindset makes all the difference in whether the student will be resilient and bounce back from difficulty or become helpless and founder (Blackwell et al. 2007; Mueller and Dweck 1998).

Changing Mindsets

Given that mindsets are influenced by messages from others, we wondered whether it would be possible to teach a growth mindset and improve students' motivation and performance as a result. To do this, we developed an eight-session workshop to teach students a growth mindset by teaching them about the brain and how it develops and grows stronger through learning. The workshop included an article, "You Can Grow Your Intelligence," images and explanations of how the brain works, and discussions about learning and growth, along with lessons on study skills. We randomly assigned seventh grade students in an urban middle school to either this growth mindset workshop or an alternative version that taught students about the brain and study skills, but without the information and activities focused on the malleable brain and developing intelligence. Both workshops were taught in the students' advisory sections by separate teams of researchers.

After the workshops, we asked the students' teachers, who were blind to the workshop condition of the students, to identify and describe those who had improved in motivation over the course of the year. Fully three-fourths of the students their teachers identified were from the growth mindset workshop group—a significant difference. Here is a typical comment a teacher made about the observed changes:

> Your workshop has already had an effect. L., who never puts in any extra effort and often doesn't turn in homework on time, actually stayed up late working for hours to finish an assignment early so I could review it and give him a chance to revise it. He earned a B+ on the assignment (he had been getting C's and lower).

We examined the students' performance in math over the course of the study. Prior to the intervention, the grades of students in both groups had very similar trajectories: they were declining from those obtained in sixth grade (the previous year) in the same school as the challenge level in the curriculum increased. And indeed, in the term following the intervention, the grades of the students in the control group continued to decline, but the grades of students in the growth mindset workshop reversed course, erasing the downturn (see Fig. 18.4) (Blackwell et al. 2007). Thus, the students who received instruction in the malleable brain and developing ability not only became more motivated, their math performance rebounded even as the curriculum continued to become more difficult over the course of seventh grade.

We have since developed and tested a blended-learning curriculum, *Brainology*®, based on this workshop, Brainology, and found that it promoted a similar shift in mindset, motivation, and performance. Here is how middle school students who completed this curriculum described the impact of learning about the malleable brain on their view of intelligence, effort, and challenge:

> You're not born dumb or born smart … Once you know how your brain works, it's much easier to control it—once you develop more neurons and connections, it's much easier to approach something that's harder for you.
>
> Probability, I was just like, "I don't get this at all. But I was just like, okay, I'm going to do this … I want to do this since it's so hard. I'm going to be like, Brain, you cannot just run away from this. I'm going to do this!

Other studies, with participants from middle school to college, have shown similar impacts

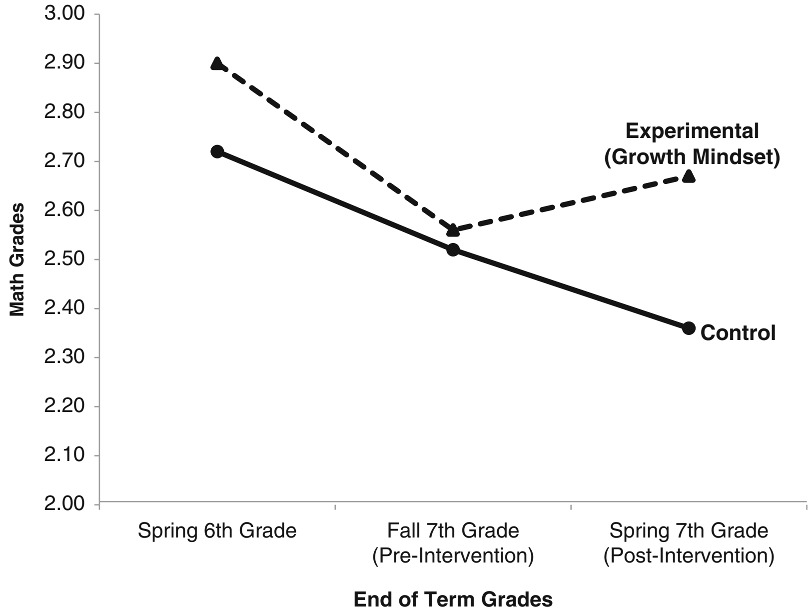

Fig. 18.4 Student achievement as a function of workshop group in Study 2 (Notes: All students' math grades had declined from the end of sixth grade to the end of the fall term in seventh grade, and there was no statistically significant difference between the two groups at either time point. Following the workshop (end of Spring seventh grade term), students in the intervention group (who learned about the malleable brain) rebounded, while the grades of students in the control group continued to decline ($p < .05$). Reprinted from Blackwell et al. 2007, p. 257. Reprinted with permission. Copyright 2007 from Society for Research in Child Development, Inc.)

of teaching a growth mindset on motivation and performance (e.g., Aronson et al. 2002; Good et al. 2003; Yeager et al. 2013). A series of new studies by David Yeager, David Paunesku, and their colleagues, for example, have found that even brief, one-time mindset interventions delivered online can lead to significant gains in achievement, including among students from traditionally underrepresented groups (Yeager et al. 2013). Thus, mindsets can be changed and motivation and achievement improved as a result.

Mindsets and the Achievement Gap

A particularly striking way that the social context can impact mindset and performance is embodied in the phenomenon of stereotype threat. Originally identified by Claude Steele and Joshua Aronson (Steele and Aronson 1995), stereotype threat occurs when students from a negatively stereotyped group (e.g., Black and Latino students in academics or female students in math and science) encounter a situation that puts them at risk of being judged in light of that stereotype and, potentially, of confirming it in the eyes of others. This concern with confirming a negative stereotype can interfere with thinking and motivation and, therefore, performance. For example, a female student taking a test of math ability given by a male administrator may worry that if she doesn't perform well, it will be seen as confirmation that females are not good at math, or a students of color taking the SAT may anticipate that their performance will be seen as reflecting on the intelligence of their race if they perform poorly.

The anticipation of such group-based negative evaluation can lead to a host of detrimental consequences, including negative thoughts (Cadinu et al. 2005; Keller and Dauenheimer 2003), anxiety (Marx and Stapel 2006), and physiological arousal that can reduce cognitive functioning (Blascovich et al. 2001; Krendl et al. 2008;

Osborne 2006, 2007; Vick et al. 2008), including working memory (Beilock et al. 2007; Schmader and Johns 2003) and attentional and behavioral control (Inzlicht et al. 2006; Smith and White 2002), especially on a challenging task (O'Brien and Crandall 2003; Stone and McWhinnie 2008), all of which can result in reduced performance and widening achievement gaps between groups (Beilock et al. 2007; Brown and Day 2006; Cadinu et al. 2005; Keller and Dauenheimer 2003; O'Brien and Crandall 2003; Schmader and Johns 2003; Steele and Aronson 1995). Thus, the preoccupation with ability and performance induced by stereotype threat can actually reduce both (at least temporarily) for students in contexts where the stereotype is relevant. However, when the task is defined as non-diagnostic of ability, the performance gap is narrowed (Aronson et al. 1999; Steele and Aronson 1995).

The negative effects of stereotype threat emerge for children as young as seven. In one set of studies (Hartley and Sutton 2013), boys underperformed on math, reading, and writing assessments when they held the belief that boys were "inferior at academics" and also when they were explicitly provided this message prior to working on the assessments. Interestingly, these effects disappeared when boys were instead told that there were no real differences in abilities between boys and girls.

Aronson and colleagues (2002) noted that the impact of stereotype threat on students—preoccupation with evaluation, anxiety during assessments, lower performance, and disidentification with academics—looked similar to the pattern observed in people with a fixed mindset concept of intelligence under conditions of challenge. Perhaps, they reasoned, teaching students to think of their abilities as malleable could buffer them against the negative effects of stereotype threat: knowing that they could always develop their ability, they would be less worried about whether they scored well on a particular test (Aronson et al. 2002). To test this, they taught students that their intelligence was malleable and then looked at their performance under conditions of stereotype threat. Teaching malleable intelligence was successful in increasing enjoyment and valuing of academics and academic performance, including GPA, among Black college students (Aronson et al. 2002). Similarly, in a study with middle school minority students, teaching about malleable intelligence raised achievement test scores in both reading and math and narrowed the achievement gap between male and female students (Good et al. 2003). Finally, explaining gender differences in math performance as the result of genetic factors rather than experience (Dar-Nimrod and Heine 2006) or effort (Thoman et al. 2008) reduced the performance of females on a math test consistent with the notion that malleable, experiential-based explanations of ability buffer students from the negative effects of stereotype threat.

These sets of studies highlight the powerful role that the psychological experience and context plays in shaping students' motivation, learning, and performance. In sum, the evidence strongly suggests that cognitive performance is the product of a synergistic relationship between individual aptitudes, beliefs, and preferences and influences from the environment, and that mindsets about intelligence are a critical part of this relationship.

Implications for Future Research

Many questions still remain to be answered regarding the interplay of mindsets and intellectual achievement. From a developmental perspective, we know too little about how early experience forges mindsets and the impact that it has on the development of talent and skills over a child's early years. In particular, research showing the emergence of the characteristic mindset patterns in young children, even before they develop a differentiated concept of intelligence, suggests that parental influence needs more investigation (Giles and Heyman 2003; Heyman et al. 2003; Smiley and Dweck 1994). The more general nature of these early mindsets raises a question of whether a more global growth or fixed mindset lies behind the much-investigated concept of ability: perhaps some children come to believe early on that people are generally fixed in their attributes, and this paradigm is later populated by more specific concepts such as intelligence, character, and the like.

How susceptible are mindsets to enduring change, and what is the minimum required intervention to drive meaningful change? Can lasting change be achieved through single point, targeted interventions teaching a growth mindset to students, or does it require a combination of malleable intelligence instruction with ongoing reinforcement through implicit messages, such as process praise? How much should we make these frameworks explicit and examined in order to transform them? Many studies indicate short-term effects of even brief growth mindset interventions (see, e.g., Yeager et al. 2013), but we do not yet know what it takes to achieve a permanent shift.

How complex and context dependent are mindsets? Note that, in much of the research literature, mindset has been treated as a global and categorical variable, contrasting fixed versus growth mindsets about general intelligence. However, it is possible to have different mindsets about different kinds of ability. For example, as shown in the studies using mindset interventions to reduce stereotype threat, some groups are vulnerable in specific subject areas, despite superior academic performance overall (e.g., females in math and science; Good et al. 2012). In addition, as we have seen, messages received from the learning environment, including our interactions with others, can impact mindset-related behavior significantly (Blackwell et al. 2007; Mueller and Dweck 1998) and can shape the neural underpinnings of the learning experience (e.g., Rodriguez et al. 2014). These findings suggest that many people may harbor mixed or flexible mindsets and rely on environmental cues to activate the one deemed most appropriate to the situation. Further research to learn more about the contextual factors that can activate different mindsets would be helpful in designing interventions and educational programs to support struggling learners.

Finally, what are the long-term consequences of holding a growth mindset for the development of one's abilities and talents? Walter Michel's impactful work has demonstrated how the tendency to delay immediate gratification during the preschool years is correlated with positive events across the lifespan (cf. Mischel et al. 2011). How does holding a growth mindset impact people over a lifetime? Research in the workplace, for example, finds that growth mindset in leadership roles ("leaders are made") can contribute to greater confidence and positive affect (Hoyt et al. 2012). Future research should continue to explore this possibility.

Implications for Educational Practice

Closing the Achievement Gap

While the debate over the nature of intelligence continues, our educational system, from K-12 to college, is grappling with the application of these concepts and measures to policy and practice, with often unintended consequences. In many schools, students are still ranked and tracked by ability based on prior achievement or their scores on assessments, exposing them to differing curricula and standards. Standing on achievement tests can be misapplied in practice as ability labels that lead both students and teachers to adopt a fixed mindset and lower expectations, which can then become a self-fulfilling prophecy. This emphasis on normative assessments and grading practices can make achievement appear to be a zero-sum game, with enormous implications due to competitive access to schools and higher education opportunities. The persistent achievement gap due to unequal educational opportunities and the psychological burden imposed by societal stereotypes for African American and Latino students and for females in math, science, and engineering still signal that a large number of our young people are laboring under identity-based fixed mindset conceptions of their ability that limit them in fulfilling their potential.

Indeed, even among individuals with both high math and verbal ability, women are less likely to pursue careers in science, technology, engineering, or math (e.g., Wang et al. 2013). These findings are especially striking because women in the Wang et al. (2003) study represented a greater percentage of those individuals with high scores on both math and verbal assessments. Recruiting students into these fields may pose challenges for additional reasons, one of these arising from the way in which these abilities are portrayed in popular media. For example, when students were presented with a (fictitious) newspaper articles conveying the biological "nature" of gender differences, readers were more likely to agree with gender stereotypes, whereas the opposite was true when social explanations were used to describe differences (Brescoll and LaFrance 2004). Explanations for group differences that rest upon biology implicitly convey a fixed mindset conception of ability and reinforce the stereotypes that can undermine motivation and achievement. Thus, both academic practices and their reflection in the popular culture can inadvertently constrain the performance of vulnerable students.

Educational Systems and Structures

The research shows that messages that highlight a person's ability, rather than their effort and process, reinforce a fixed mindset and often precipitate a helpless pattern when the person encounters difficulty. However, while individual teachers can change the way they praise and criticize students in their classroom, they also operate within a larger context of assessment and incentives that are not informed by this research. For example, most schools and districts still adhere to one-size-fits all curricula and standards with age and grade-level expectations, grade students in comparison to their peers on a rigid timeline, and rely on a small number of high-stakes tests to measure student and school success and to select students for access to future learning opportunities. For students who initially lack foundational skills and learning strategies, these policies may virtually ensure failure and undermine the focus on process and growth that are critical to promoting positive motivation.

Recent research suggests that motivation-related behaviors, such as "grit" and perseverance in pursuing goals, may be more predictive of success than IQ; for example, Angela Duckworth and colleagues have found that students who exhibited greater self-control earned higher grades, whereas students' IQ scores were not related to achievement (Duckworth and Seligman 2005). We know from a large body of research that teaching content in the absence of positive academic mindsets and basic learning skills often falls short and that programs aimed at changing students' learning behavior directly are less effective than interventions that change their mindsets. (See Farrington et al. 2012 for a review.) Yet the vast majority of our educational efforts are devoted to core subject curriculum and assessment, sometimes at the expense of teaching academic mindsets and foundational learning skills.

The evidence shows that intellectual development and performance are highly dependent on the interaction of environmental supports and individual effort and active engagement—and that practices that instill and nurture a growth mindset also promote and sustain effort, engagement, and achievement. What could we achieve if, rather than measuring and comparing students with one another, we focused on providing them with a solid foundation of self-efficacy and skills and then on creating opportunities for them to grow? With the knowledge we have gained from decades of research in the role of mindsets in achievement, we have the opportunity to provide the current generation of learners—and their teachers—with a solid foundation for future growth.

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Creativity and Intelligence

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Creativity and Intelligence

Given the importance of the construct of human intelligence, it is not surprising that the relationship between intelligence and other constructs has been frequently studied. For example, psychologists maintain active research programs on the relationship between intelligence and working memory (Burgess et al. 2011), intelligence and bias in logical thinking (Stanovich, West, and Toplak 2013), and – increasingly – intelligence and health (Deary et al. 2010).

The potential association of creativity and intelligence has consistently received attention, with the early scientific studies of intelligence (e.g., Galton's *Hereditary Genius,* 1869) overlapping considerably with the constructs of creativity and talent development. Several seminal studies of creativity focus at least in part on intelligence (e.g., Barron 1963; Getzels and Jackson 1962; Wallach and Kogan 1965); indeed, one of the first leading creativity researchers, J. P. Guilford, began by studying intelligence (Guilford 1967). This attention is due, in part, to the fact that both constructs are integral to understanding talent and giftedness, and scholarship on gifted education has traditionally included studies in this area.

As Sternberg and O'Hara (1999) observed, the degree to which creativity and intelligence are related – and the nature of any such relationship – is "theoretically important, and its answer probably affects the lives of countless children and adults" (p. 269), and Plucker and Renzulli (1999) concluded that it is now not a matter of discovering *whether* intelligence and creativity are related, but rather of *how* they are related. Although those sentiments are nearly a generation old at this point, the amount of theoretical and empirical work on the topic has continued to grow (e.g., J. C. Kaufman and Plucker 2011; Kell et al. 2013; Kim et al. 2010), providing evidence that the topic will remain popular into the future.

Another reason for heightened attention is the growing popularity of the "21st century skills" in education systems around the globe. Many models and frameworks of these skills include constructs that are similar, if not identical, to intelligence and creativity (see Partnership for 21st Century Skills 2013). These models implicitly endorse the view that problem solving is a

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key competency for both life and workplace success and that intelligence and creativity are integral parts of the ability to solve problems effectively and efficiently.

The specific relationship of intelligence and creativity to each other and to general problem solving or other positive outcomes has tremendous practical implications. If intelligence and creativity are very closely entwined, for example, then an overdependence on ability and achievement measures (such as the college entrance examinations) would be less worrisome. If the two constructs are only slightly related, then workplaces that value both intelligence and creativity would need to make sure to specifically assess both abilities. At a broader level, if intelligence and creativity are essential and distinct components for successful problem solving, then we need to make sure that our schools and workplaces are doing their best to nurture and support both abilities.

In What Ways Can Intelligence and Creativity Be Related?

Despite the importance of the creativity-intelligence relationship, a novice reading the literature for the first time could be forgiven for walking away bewildered: The breadth of theoretical treatments is vast, and there is surprisingly little empirical convergence. For example, threshold theory suggests intelligence is a necessary but not a sufficient condition of creativity (Barron 1969; Yamamoto 1964), certification theory focuses on environmental factors that allow people to display creativity and intelligence (Hayes 1989), and an interference hypothesis suggests that very high levels of intelligence may interfere with creativity (Simonton 1994; Sternberg 1996).

To complicate things further, intelligence and creativity are each time-consuming to assess well. Most studies use divergent thinking tests to measure creativity and group-based tests of *g* to measure intelligence (see Barron and Harrington 1981; Kim 2005). Although group IQ tests serve a strong purpose in research studies, they are not considered ideal for psychoeducational assessment (A. S. Kaufman and Lichtenberger 2006). In addition, most current IQ tests use the Cattell-Horn-Carroll (CHC; see Flanagan et al. 2007) model or other cognitive theories (e.g., Das et al. 1994) to give separate index scores in addition to producing an overall *g* score (A. S. Kaufman 2009). Plucker and Esping (2014) note that this bemusement is completely understandable, and they recommend focusing on the definitions of the constructs being studied in order to wade through and understand the wide range of conceptualizations. Although they were specifically talking about definitions of intelligence, the recommendation holds for definitions of creativity, and certainly (and perhaps most appropriately!) for comparisons of the two constructs.

Fortunately, Sternberg and O'Hara (1999) provide a framework for examining the construct definitions. Although Sternberg's approach is nearly 15 years old, a similarly productive alternative has not been subsequently proposed, and most, if not all, subsequent research fits into his framework. Due to the durability and usefulness of the model, we use it as the framework for this chapter. Sternberg's model suggests five possible relationships: creativity as a subset of intelligence, intelligence as a subset of creativity, creativity and intelligence as overlapping sets, creativity and intelligence as coincident sets, and creativity and intelligence as disjoint sets. In the following sections, we provide examples of each type of relationship. The last two categories, coincident and disjoint sets, are quite rare and are not described here.[1]

Creativity as a Subset of Intelligence

A number of psychometric theories include creativity, either explicitly or implicitly, as a part of intelligence, such as Guilford's Structure of the Intellect (SOI; 1967) model. He specifically included divergent thinking as a cognitive operation within the SOI model – many of the divergent thinking assessments used over the past 50

[1] That said, Nusbaum and Silvia (2011) offer some evidence of a coincident set perspective, which bears watching for future developments.

years originated from this model, and Renzulli (1973) developed a creativity curriculum based on the divergent thinking operation.

Gardner (1993), coming at the constructs from his developmental and qualitative perspective, has used Multiple Intelligence Theory to study creativity, implicitly suggesting that creativity is a subset of MI Theory. In Gardner's seminal book, *Creating Minds*, he used case studies of eminent creators to argue that people can excel creatively as a function of embodying different intelligences. For example, he highlighted Picasso (spatial intelligence), Freud (intrapersonal), Stravinsky (musical), Einstein (logical-mathematical), T. S. Eliot (linguistic), Martha Graham (bodily-kinesthetic), and Gandhi (interpersonal).

Another theory that includes creativity as a core component is Sternberg's (1996, 1997, 1999; Sternberg et al. 2008) theory of successful intelligence. This theory comprises three "subtheories": a *componential subtheory*, which relates intelligence to the internal world of the individual; an *experiential subtheory*, which relates intelligence to both the external and the internal worlds of the individual; and a *contextual subtheory*, which relates intelligence to the external world of the individual. The componential subtheory specifies the mental mechanisms responsible for planning, carrying out, and evaluating intelligent behavior. The experiential subtheory expands on this definition by focusing on those important behaviors that involve either adjustment to relative novelty, automatization of information processing, or both. The contextual subtheory defines intelligent behavior as involving purposeful adaptation to, selection of, and shaping of real-world environments relevant to one's life (Sternberg et al. 2008). The experiential subtheory is directly related to creativity. Sternberg's application of creativity assessments to admissions data increased prediction of college success beyond that obtained with standard admissions tests; in addition, ethnic-group differences were significantly reduced (Sternberg 2006, 2010, 2012; Sternberg and The Rainbow Project Collaborators 2005, 2006).

The Cattell-Horn-Carroll (CHC) model of intelligence also includes creativity as a subset of intelligence. The CHC model is a combination of the Cattell-Horn theory of fluid and crystallized intelligence (Horn and Cattell 1966, 1967) and Carroll's (1993) Three-Stratum Theory. Both the Cattell-Horn and Carroll models essentially take Spearman's (1904) *g*, with Horn and Cattell proposing two distinct forms of *g:* fluid intelligence (*Gf*), the ability to apply a variety of mental operations to solve novel problems, and crystallized intelligence (*Gc*), the breadth and depth of a person's accumulated knowledge of a culture and the ability to use that knowledge to solve problems (Horn and Cattell 1966; see also Horn and Blankson 2005).

Creativity was originally hypothesized to be strongly associated to *Gf* in the early stages of the Cattell-Horn *Gf-Gc* theory (Cattell and Butcher 1968). However, this connection is no longer explicitly part of the CHC theory, in part because empirical support has been mixed, with some studies supporting a link between Gc and creativity (Batey et al. 2009; Cho et al. 2010; Furnham and Chamorro-Premuzic 2006) and others providing evidence of a Gf-creativity link (Batey et al. 2010a, b; Nusbaum and Silvia 2011).

In current versions of CHC theory, creativity is primarily placed under the category of long-term storage and retrieval (*Glr*), the ability to store information in and fluently retrieve new or previously acquired information (e.g., concepts, ideas, items, names) from long-term memory. Indeed, *Glr* explicitly includes originality/creativity as one of its components (Flanagan et al. 2007). *Glr* has two parts, *learning efficiency* (learning and retaining new information) and *fluency* (generating many different possible solutions). Carroll (1993) proposed that these two parts were distinct abilities, labeled memory and learning and idea production, respectively. With the creation of CHC theory (McGrew 2005), they were combined into *Glr*. Carroll's idea production has long been associated with creativity (Schneider and McGrew 2012), most notably Guilford's (1967) operation of divergent production.

McGrew (2009) recently noted that "Some *Glr* narrow abilities have been prominent in creativity research (e.g., production, ideational fluency, or associative fluency)" (p. 6). In an otherwise detailed description of the model, this sentence is the only mention of creativity, originality, or divergent thinking. Fluid intelligence (*Gf*) is discussed in terms of its relationship to problem solving and coping with novel problems (both considered to be highly related to creativity). Nonetheless, in current discussions of the relationship of creativity to intelligence as presented by the CHC model, the emphasis is on *Glr*. Several of the narrow abilities incorporated into *Glr*, such as ideational fluency, associational fluency, and originality/creativity (obviously), have been specifically hypothesized to relate strongly to creativity (Kaufman et al. 2011).

There is a striking lack of studies on how creativity is empirically connected to *Glr*. Very recently, Silvia et al. (2013) conducted one of the few studies to examine this relationship. They examined how divergent thinking performance related to multiple verbal fluency tests (representing the lower-order *Glr* factors related to fluency). Silvia et al. found that the larger *Glr* factor had a significant effect on both fluency and originality in divergent thinking.

There is much more work to be done, and this gap is notable not only because of the theoretical link between *Glr* and creativity but also because of the existing work on the positive link between memory and creativity. Much of the work on creative cognition, from Wallas (1926) and later scholars (Finke et al. 1992; Mumford et al. 1991) to neuropsychological models (Bristol and Viskontas 2006; Gabora 2010), discusses cognitive processes that apply preexisting knowledge to new concepts. Mednick's (1962) theory of remote associations posited that the ability to organize and access ideas aided creativity by allowing for more remote associations between ideas.

Mednick's (1968) measure, the Remote Associates Test, is a common measure of creative problem solving that requires people to find a word that is associated with three other words (e.g., sleeping, bean, and trash are all connected to the word bag). Storm et al. (2011) found that when people take the Remote Associates Test, they are more likely to forget other common associated words. This *goal-directed forgetting* (Bjork et al. 1998) is linked to better creative problem solving.

An interesting extension of the CHC perspective was provided by Martindale (1999), who proposed that people who are creative are selective with their information processing speed. Early in the creative process, they focus on processing larger amounts of information, but as the problem in question becomes better understood, they shorten their attention span, thereby increasing their processing speed. Martindale's work is similar to Sternberg's (1981) hypothesis that brighter people spend more time in initial global planning so that they do not have to spend as much time in local planning later in the process.

A relatively new theory, the Dual Process Theory of Intelligence (S. B. Kaufman 2013), treats creativity as a subset of intelligence. S. B. Kaufman (2013), in an attempt to combine cognitive models with intelligence research, posits a two-factor model of intelligence, with one factor representing controlled cognition (type 1) – goal-directed thoughts and actions that include, but are entirely explained by, *g* – and one representing spontaneous cognition (type 2) – unconsciousness-related thoughts and actions that include implicit learning ability and daydreaming, among many other constructs.

In S. B. Kaufman's view, creativity results from the combination of type 1 and type 2 processes, with the role and importance of each type of process varying during any specific individual's creative process. S. B. Kaufman notes the pertinent research of Vartanian (2009) and colleagues (Vartanian et al. 2009), in which they provide evidence that creative individuals may have the ability to focus attention to varying degrees depending on the context in which their creative cognition is occurring and the type of creative activity undertaken.

Intelligence as a Subset of Creativity

In contrast, other researchers have hypothesized that intelligence is a part of creativity. Although this approach has received scant attention among intelligence researchers, systems models of creativity tend to emphasize the contribution of intelligence and related cognitive processes as one factor among many that influence the development of creativity. As systems theories have grown in prevalence in the social sciences, they have grown in importance within creativity (Kozbelt et al. 2010), making this conceptual category rather more popular than in the earlier years of the field.

One major creativity theory that includes intelligence is Sternberg and Lubart's (1996) "investment" theory, in which they use the metaphor of the stock market. The key to being creative, they argue, is to buy low and sell high with your ideas. In this model, a successful creator will have ideas that may be at first be unpopular or underappreciated yet will preserve and eventually persuade other people that his or her ideas are valuable. The creator will then know at what point to move on to pursue other ideas.

According to this theory, six main elements contribute to successful creativity: intelligence, knowledge, thinking styles, personality, motivation, and the environment. Intelligence contributes using three elements drawn from Sternberg's triarchic theory (1988, 1996; later expanded into the theory of successful intelligence as described earlier).

Another theory that casts creativity as being a blend of different abilities is Amabile's (1982, 1996) componential model of creativity. She argued that three variables were needed for creativity to occur: domain-relevant skills, creativity-relevant skills, and task motivation. Domain-relevant skills include knowledge, technical skills, and specialized talent (i.e., a creative writer should know basic grammar and styles). Creativity-relevant skills are more personal factors that have been associated with creativity. These can include tolerance for ambiguity, self-discipline, and risk-taking. Finally, Amabile highlights motivation (intrinsic or extrinsic) toward the task at hand. Intelligence would primarily occur at the domain-relevant skill level.

A third theory that accounts for multiple variables but takes a more domain-specific approach is the Amusement Park Theoretical Model (APT Model; Baer and Kaufman 2005; Kaufman and Baer 2004). In an amusement park, there are *initial requirements* (e.g., a ticket, a ride to the location) that apply to all areas of the park. Similarly, there are initial requirements that, to varying degrees, are necessary for creative performance in all domains. One such essential initial requirement is intelligence. There are then a series of subcomponents, *general thematic areas*, *domains*, and *microdomains*, that get more and more specific (e.g., social sciences to psychology to educational psychology). Different aspects of intelligence that are more or less important across these specific areas, for example, *Gc*, might be particularly important to a historian, whereas *Gf* might be essential for an engineer.

Overlapping Sets

Sternberg's third grouping conceptualizes intelligence and creativity as overlapping yet distinct constructs. Renzulli's (1978) three-ring conception of giftedness theorizes that giftedness – implicitly cast as high-level creative production – is caused by the overlap of high intellectual ability, creativity, and task commitment. From this perspective, creativity and intelligence are distinct constructs but overlap considerably under the right conditions. In a similar vein, the concept of planning abilities in the planning, attention-arousal, simultaneous and successive (PASS) theory appears to overlap with creativity (Naglieri and Kaufman 2001), and Plucker et al. (2004) view creativity and intelligence as related but distinct in their definition of creativity as "the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (p. 90).

Threshold Theory. Traditional research has argued for a *threshold theory*, in which creativity and intelligence are positively, if moderately, correlated up until an IQ of approximately 120; in people with higher IQs, the two constructs show little relationship (e.g., Fuchs-Beauchamp et al. 1993; Getzels and Jackson 1962). Sternberg places this perspective in the overlapping sets category. This view is so common as to be considered part of the conventional wisdom about creativity, intelligence, and giftedness.

Yet some recent work has called into question the presence of a threshold (whether lower or higher than a 120 IQ). For example, Preckel et al. (2006) studied *Gf* and creativity (as measured through divergent thinking tests) and found modest correlations across all levels of intellectual abilities. In a meta-analysis of 21 studies, Kim (2005) found virtually no support for the threshold theory; there were small positive correlations between measures of ability and measures of creativity and divergent thinking.

Many of the early studies that formed the basis of threshold theory would now be considered quite dated. Any study conducted before the 1970s would have (obviously) used measures of intelligence that do not reflect current theory. Other studies have defined creativity rather narrowly as being only divergent thinking or the ability to generate multiple ideas in response to a single prompt.

Fortunately, researchers have begun to address these limitations, with interesting results. For example, Sligh et al. (2005) used a contemporary, individually administered IQ test (Kaufman Adolescent and Adult Intelligence Test; A. S. Kaufman and Kaufman 1993) and a creative invention task (in which people use shapes to create product objects and then name and describe their invention; see Finke 1990). By assessing both *Gc* and *Gf*, they were able to show moderate, positive correlations between *Gc* and creativity (i.e., similar to previous studies); however, intelligence and creativity were significantly correlated for the high-IQ group, which was not the case for people with average intelligence scores – an opposite pattern than predicted by threshold theory.

In a similar line of research (but with much different participants), the Study of Mathematically Precocious Youth has been following a cohort of students from late childhood/early adolescence into adulthood. These students all scored in the top 1 % on college entrance examinations before the age of 13, so they are a very bright group. Park et al. (2007, 2008) found that, within this very intelligent group, intellectual talent was highly correlated with educational attainment. This by itself is not surprising, but they also found that a range of indicators of adult creative accomplishments (e.g., patents, publications, awards) was also correlated with intelligence. Wai et al. (2005), looking at the same population, found that differences in SAT scores – even within such an elite group – predicted creative accomplishments 20 years later. These results, emerging as they do from studies that address the limitations of previous research, raise serious doubts about the threshold effect, and they firmly reflect a belief in the overlapping sets perspective.

Recent research by Beaty and Silvia (2012) provides potential insight into the mechanisms at play here. They had college students complete divergent thinking tasks over a 10-min period, and they unsurprisingly found that participants reported more creative ideas as they progressed throughout the session, as time marched on. However, they also administered a *Gf* measure, and – surprisingly – the higher the *Gf* score, the flatter the slope of the creativity-time curve. This means that the most intelligent people in their sample did not come up with appreciably more creative ideas over time, rather providing fairly creative ideas from the beginning to the end of the session. Less intelligent participants had increasingly steep slopes, meaning that they definitely were more creative as time progressed. This study raises the possibility that there are underlying cognitive mechanisms behind recent observations that intelligence and creativity are correlated even at high levels of intelligence and that those mechanisms may be a combination of executive processes related to information retrieval and manipulation and associative processes that involve activation of various parts of one's cognitive schema.

One recent study, by Jauk et al. (2013), uses sophisticated statistical techniques to support the threshold effect, if not the traditional cutoff level. They used segmented regression analysis and found that the threshold level varied based on the creativity score used. Ideational fluency's threshold was at an IQ of 86 (which is astoundingly lower than the more traditional 120); if the top two originality scores were used, the threshold was 104.

Conclusion

Each of the five possible relationships in Sternberg's framework enjoys at least some empirical support (Sternberg and O'Hara 1999; Kaufman and Plucker 2011), but the difficulty in interpreting empirical results illustrates the problems associated with reaching a consensus on the validity of any of these five relations. For example, Haensly and Reynolds (1989) believe that Mednick's (1962) Association Theory supports the creativity as a subset of intelligence position, yet Sternberg and O'Hara (1999) feel that this body of work supports the overlapping sets position. If Gardner's work with creativity had come before his work with MI Theory, we would probably be arguing that his efforts fall within the intelligence as a subset of creativity category.

As Plucker and Esping (2014) note, definitions are critically important when dealing with psychological constructs, as the way in which each construct is conceptualized and assessed will have a significant impact on any empirical results when comparing two or more constructs. As this chapter has showed, the range of creativity and intelligence definitions makes the complexity of possible intelligence-creativity relationships unsurprising. Few people believe creativity and intelligence are completely unrelated, but the nature of any relationship – even with so much research already conducted – is an open question.

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