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DEPARTMENT OF PSYCHOLOGY

STUDY MATERIALS

18MPS11C-HISTORY OF PSYCHOLOGY

CONTENTS:

UNIT – IV : INTELLIGENCE

Expert opinions on the nature of intelligence – The seminal views of Galton and Binet – Models of the nature of intelligence – Intelligence as arising from cognitive structures and processes – Biological bases of intelligence – Role of culture and society in intelligence – Systems models.

UNIT-4

INTELLIGENCE

Anyone who has seriously studied the history of the United States or of any other country knows that there is not one history of the country but many histories. The history as told by some Native Americans, for example, would look quite different from the history as told by some of the later settlers, and even within these groups, the stories would differ. Similarly, there is no one history of the field of intelligence but rather many histories, depending on who is doing the telling. For example, the largely laudatory histories recounted by Carroll (1982, 1993), Herrnstein and Murray (1994), and Jensen (in press) read very differently from the largely skeptical histories recounted by Gardner (1983, 1999), Gould (1981), or Sacks (1999). And of course, there are differences within these groups of authors.

These differences need mentioning because, although all fields of psychology are subject to being perceived through ideological lenses, few fields seem to have lenses with so many colors and, some might argue, with so many different distorting imperfections as do the lenses through which is seen the field of intelligence. The different views come from ideological biases affecting not only what is said but also what is included. For example, there is virtually no overlap in the historical data used by Carroll (1993) versus Gardner (1983) to support their respective theories of intelligence.

Although no account can be truly value free, I try in this chapter to clarify values in three ways. First, I attempt to represent the views of the investigators and their times in presenting the history of the fifield. Second, I critique this past work but make it clear what my own personal opinions are by labeling evaluative sections "Evaluation." Third, I try to represent multiple points of view in a dialectical fashion (Hegel, 1807/1931; see R. J. Sternberg, 1999a), pointing out both the positive and negative sides of various contributions. This representation recognizes that all points of view taken in the past can be viewed, with "20/20 hindsight," as skewed, in much Preparation of this chapter was supported by Grant REC-9979843 from the National Science Foundation and by a grant under the Javits Act Program (Grant No. R206R000001) as administered by the Offifice of Educational Research and Improvement, U.S. Department of Education. Grantees undertaking such projects are encouraged to express freely their professional judgment. This chapter, therefore, does not necessarily represent the position or policies of the National Science Foundation, Office of Educational Research and Improvement, or the U.S. Department of Education, and no official endorsement should be inferred the same way that present points of view will be viewed as skewed in the future. A dialectical form of examination will serve as the basis for the entire chapter. The basic idea is that important ideas, good or bad, eventually serve as the springboard for new ideas that grow out of unions of past ideas that may once have seemed incompatible.

The emphasis in this chapter is on the history of the fifield of intelligence, particularly with reference to theories of intelligence.

Readers interested in contemporary theory and research are referred to the chapter “Contemporary Theories of Intelligence” in Volume 7 of this handbook (R. J. Sternberg, 2002). Such theories and research are mentioned only in passing in this chapter. Readers interested primarily in measurement issues might consult relevant chapters in R. J. Sternberg (1982, 1994, 2000).

Perhaps the most fundamental dialectic in the fifield of intelligence arises from the question of how we should conceive of intelligence. Several different positions have been staked out (Sternberg, 1990a). Many of the differences in ideology that arise in accounts of the history of the field of intelligence arise from differences in the model of intelligence to which an investigator adheres. To understand the history of the field of intelligence, one must understand the alternative epistemological models that can give rise to the concept of intelligence.

But before addressing these models, consider simply the question of how psychologists in the field of intelligence have defined the construct on which they base their models.

EXPERT OPINIONS ON THE NATURE OF INTELLIGENCE

Historically, one of the most important approaches to fifiguring out what intelligence is has relied on the opinions of experts. Such opinions are sometimes referred to as *implicit theories*, to distinguish them from the more formal *explicit theories*that serve as the bases for scientifific hypotheses and subsequent data collections. Implicit theories (which can be those of laypersons as well as of experts) are important to the history of a field for at least three reasons (R. J. Sternberg, Conway, Ketron, & Bernstein, 1981). First, experts’ implicit theories are typically what give rise to their explicit theories. Second, much of the history of intelligence research and practice is much more closely based on implicit theories than it is on formal theories. Most of the intelligence tests that have been used, for example, are based more on the opinions of their creators as to what intelligence is than on formal theories. Third, people's everyday judgments of each other's intelligence always have been and continue to be much more strongly guided by their implicit theories of intelligence than by any explicit theories.

Intelligence Operationally Defined

E. G. Boring (1923), in an article in the *New Republic*, proposed that intelligence is what the tests of intelligence test. Boring did not believe that this operational definition was the end of the line for understanding intelligence. On the contrary, he saw it as a "narrow definition, but a point of departure for a rigorous discussion... until further scientific discussion allows us to extend [it]" (p. 35). Nevertheless, many psychologists and especially testers and interpreters of tests of intelligence have adopted this definition or something similar to it. From a scientific point of view, the definition is problematical. First, the definition is circular: It defines intelligence in terms of what intelligence tests test, but what the tests test can only be determined by one's definition of intelligence. Second, the definition legitimates rather than calling into scientific question whatever operations are in use at a given time to measure intelligence. To the extent that the goal of science is to disconfirm existing scientific views (Popper, 1959), such a definition will not be useful. Third, the definition assumes that what intelligence tests test is uniform. But this is not the case. Although tests of intelligence tend to correlate positively with each other (the so-called *positive manifold* first noted by Spearman, 1904), such correlations are far from perfect, even controlling for unreliability. Thus, what an intelligence test tests is not just one uniform thing. Moreover, even the most ardent proponents of a general factor of intelligence (a single element common to all of these tests) acknowledge there is more to intelligence than just the general factor.

The 1921 Symposium

Probably the most well-known study of experts' definitions of intelligence was one done by the editors of the *Journal of Educational Psychology* ("Intelligence and Its Measurement," 1921). Contributors to the symposium were asked to write essays addressing two issues: (a) what they conceived intelligence to be and how it best could be measured by group tests, and (b) what the most crucial next steps would be in research. Fourteen experts gave their views on the nature of intelligence, with such defifinitions as the following:

1. The power of good responses from the point of view of truth or facts (E. L. Thorndike).

2. The ability to carry on abstract thinking (L. M. Terman).

3. Sensory capacity, capacity for perceptual recognition, quickness, range or flexibility of association, facility and imagination, span of attention, quickness or alertness in response (F. N. Freeman).

4. Having learned or ability to learn to adjust oneself to the environment (S. S. Colvin).

5. Ability to adapt oneself adequately to relatively new situations in life (R. Pintner).

6. The capacity for knowledge and knowledge possessed (B. A. C. Henmon).

7. A biological mechanism by which the effects of a complexity of stimuli are brought together and given a somewhat unified effect in behavior (J. Peterson).

8. The capacity to inhibit an instinctive adjustment, the capacity to redefine the inhibited instinctive adjustment in the light of imaginally experienced trial and error, and the capacity to realize the modified instinctive adjustment in overt behavior to the advantage of the individual as a social animal (L. L. Thurstone).

9. The capacity to acquire capacity (H. Woodrow).

10. The capacity to learn or to profifit by experience (W. F. Dearborn).

11. Sensation, perception, association, memory, imagination, discrimination, judgment, and reasoning (N. E. Haggerty).

Others of the contributors to the symposium did not provide clear definitions of intelligence but rather concentrated on how to test it. B. Ruml refused to present a definition of intelligence, arguing that not enough was known about the concept. S. L. Pressey described himself as uninterested in the question, although he became well known for his tests of intelligence.

Of course, there have been many definitions of intelligence since those represented in the journal symposium, and an essay even has been written on the nature of definitions of intelligence (Miles, 1957). One well-known set of definitions was explicitly published in 1986 as a follow-up to the 1921 symposium (R. J. Sternberg & Detterman, 1986). R. J. Sternberg and Berg (1986) attempted a comparison of the views of the experts in 1986 (P. Baltes, J. Baron, J. Berry, A. Brown and J. Campione, E. Butterfifield, J. Carroll, J. P. Das, D. Detterman, W. Estes, H. Eysenck, H. Gardner, R. Glaser, J. Goodnow, J. Horn, L. Humphreys, E. Hunt, A. Jensen, J. Pellegrino, R. Schank, R. Snow, R. Sternberg, E. Zigler) with those of the experts in 1921. They reached three general conclusions.

First, there was at least some general agreement across the two symposia regarding the nature of intelligence. When attributes were listed for frequency of mention in the two symposia, the correlation was .50, indicating moderate overlap. Attributes such as adaptation to the environment, basic mental processes, higher-order thinking (e.g., reasoning, problem solving, and decision making) were prominent in both symposia.

Second, central themes occurred in both symposia. One theme was the one versus the many: Is intelligence one thing or is it multiple things? How broadly should intelligence be defined? What should be the respective roles of biological and behavioral attributes in seeking an understanding of intelligence?

Third, despite the similarities in views over the 65 years, some salient differences could also be found. Metacognition— conceived of as both knowledge about and control of cognition—played a prominent role in the 1986 symposium but virtually no role at all in the 1921 symposium. The later symposium also placed a greater emphasis on the role of knowledge and the interaction of mental processes with this knowledge. Definitions of any kind can provide a basis for explicit scientific theory and research, but they do not provide a substitute for these things. Thus, it was necessary for researchers to move beyond definitions, which they indeed did. Many of them moved to models based on individual differences.

Intelligence as Arising from Individual Differences:

The Differential Model

McNemar (1964) was one of the most explicit in speculating on why we even have a concept of intelligence and in linking the rationale for the concept to individual differences. He queried whether two identical twins stranded on a desert island and growing up together ever would generate the notion of intelligence if they never encountered individual differences in their mental abilities.

Perhaps without individual differences, societies would never generate the notion of intelligence and languages would contain no corresponding term. Actually, some languages, such as Mandarin Chinese, in fact have no concept that corresponds precisely to the Western notion of intelligence (Yang & Sternberg, 1997a, 1997b), although they have related concepts that are closer, say, to the Western notion of wisdom or other constructs. Whatever may be the case, much of the history of the field of intelligence is based upon an epistemological model deriving from the existence of one or more kinds of individual differences.

THE SEMINAL VIEWS OF GALTON AND BINET

If current thinking about the nature of intelligence owes a debt to any scholars, the debt is to Sir Francis Galton and to Alfred Binet. These two investigators—Galton at the end of the nineteenth century and Binet at the beginning of the twentieth century—have had a profound impact on thinking about intelligence, an impact that has carried down to the present day. Many present conflicts of views regarding the nature of intelligence can be traced to a dialectical conflict between Galton and Binet.

Intelligence Is Simple: Galton's Theory of Psychophysical Processes

Intelligence as Energy and Sensitivity

The publication of Darwin's *Origin of Species* (1859) had a profound impact on many lines of scientific endeavor. One was the investigation of human intelligence. The book suggested that the capabilities of humans were in some sense continuous with those of lower animals and hence could be understood through scientific investigation.

Galton (1883) followed up on these notions to propose a theory of the "human faculty and its development." Because he also proposed techniques for measuring the "human faculty," his theory could be applied directly to human behavior. Galton proposed two general qualities that he believed distinguish the more from the less intellectually able. His epistemological rooting, therefore, was in the individual differences approach. The first quality was *energy,* or the capacity for labor. Galton believed that intellectually gifted individuals in a variety of fields are characterized by remarkable levels of energy. The second general quality was *sensitivity*. He observed that the only information that can reach us concerning external events passes through the senses and that the more perceptive the senses are of differences in luminescence, pitch, odor, or whatever, the larger would be the range of information on which intelligence could act. Galton's manner of expression was direct: The discriminative facility of idiots is curiously low; they hardly distinguish between heat and cold, and their sense of pain is so obtuse that some of the more idiotic seem hardly to know what it is. In their dull lives, such pain as can be excited in them may literally be accepted with a welcome surprise. (p. 28)

For seven years (1884–1890), Galton maintained an anthropometric laboratory at the South Kensington Museum in London where, for a small fee, visitors could have themselves measured on a variety of psychophysical tests. What, exactly, did these kinds of tests look like? One such test was weight discrimination. The apparatus consisted of shot, wool, and wadding. The cases in which they were contained were identical in appearance and differed only in their weights. Participants were tested by a sequencing task. They were given three cases, and with their eyes closed, they had to arrange them in proper order of weight. The weights formed a geometric series of heaviness, and the examiner recorded the finest interval that an examinee could discriminate. Galton suggested that similar geometric sequences could be used for testing other senses, such as touch and taste. With touch, he proposed the use of wirework of various degrees of fineness, whereas for taste, he proposed the use of stock bottles of solutions of salt of various strengths. For olfaction, he suggested the use of bottles of attar of rose mixed in various degrees of dilution.

Galton also contrived a whistle for ascertaining the highest pitch that different individuals could perceive. Tests with the whistle enabled him to discover that people’s ability to hear high notes declines considerably as age advances. He also discovered that people are inferior to cats in their ability to perceive tones of high pitch. It is ironic, perhaps, that a theory that took off from Darwin’s theory of evolution ended up in what some might perceive as a predicament, at least for those who subscribe to the notion that evolutionary advance is, in part, a matter of complexity (Kauffman, 1995). In most respects, humans are evolutionarily more complex than cats. Galton's theory, however, would place cats, which are able to hear notes of higher pitch than humans, at a superior level to humans, at least with respect to this particular aspect of what Galton alleged to be intelligence.

Cattell's Operationalization of Galton's Theory

James McKeen Cattell brought many of Galton's ideas across the ocean to the United States. As head of the psychological laboratory at Columbia University, Cattell was in a good position to publicize the psychophysical approach to the theory and measurement of intelligence. Cattell (1890) proposed a series of 50 psychophysical tests. Four examples were:

1. *Dynamometer pressure.* The dynamometer-pressure test measures the pressure resulting from the greatest possible squeeze of one's hand.

2. *Sensation areas.* This test measures the distance on the skin by which two points must be separated in order for them to be felt as separate points. Cattell suggested that the back of the closed right hand between the fifirst and second fifingers be used as the basis for measurement.

3. *Least noticeable difference in weight.* This test measures least noticeable differences in weights by having participants judge weights of small wooden boxes. Participants were handed two such boxes and asked to indicate which was heavier.

4. *Bisection of a 50-cm line.* In this test, participants were required to divide a strip of wood into two equal parts by means of a movable line.

Wissler Blows the Whistle

A student of Cattell's, Clark Wissler (1901), decided to validate Cattell's tests. Using 21 of these tests, he investigated among Columbia University undergraduates the correlations of the tests with each other and with college grades. The results were devastating: Test scores neither intercorrelated much among themselves, nor did they correlate significantly with undergraduate grades. The lack of correlation could not have been due entirely to unreliability of the grades or to restriction of range, because the grades did correlate among themselves. A new approach seemed to be needed.

Evaluation

Even those later theorists who were to build on Galton's work (e.g., Hunt, Frost, & Lunneborg, 1973) recognize that Galton was overly simplistic in his conception and measurement of intelligence. Galton was also pejorative toward groups whom he believed to be of inferior intelligence. Yet one could argue that Galton set at least three important precedents.

A first precedent was the desirability of precise quantitative measurement. Much of psychological measurement, particularly in the clinical areas, had been more qualitative, or has been based on dubious rules about translations of qualitative responses to quantitative measurements. Galton's psychometric precision set a different course for research and practice in the field of intelligence. His combination of theory and measurement techniques set a precedent: Many future investigators would tie their theories, strong or weak, to measurement operations that would enable them to measure the intelligence of a variety of human populations. A second precedent was the interface between theory and application. Galton's Kensington Museum enterprise set a certain kind of tone for the intelligence measurement of the future. No field of psychology, perhaps, has been more market oriented than has been the measurement of intelligence.

Testing of intelligence has been highly influenced by market demands, more so, say, than testing of memory abilities or social skills. It is difficult to study the history of the field of intelligence without considering both theory and practice.

A third precedent was a tendency to conflate scores on tests of intelligence with some kind of personal value. Galton made no attempt to hide his admiration for hereditary geniuses (Galton, 1869) nor to hide his contempt for those at the lower end of the intelligence scale as he perceived it (Galton, 1883). He believed those at the high end of the scale had much more to contribute than did those at the low end. The same kinds of judgments do not pervade the literatures of, say, sensation or memory. This tendency to conflate intelligence with some kind of economic or social value to society and perhaps beyond society has continued to the present day (e.g., Herrnstein & Murray, 1994; Schmidt & Hunter, 1998).

Intelligence Is Complex: Binet's Theory of Judgment

In 1904, the minister of Public Instruction in Paris named a commission charged with studying or creating tests that would ensure that mentally defective children (as they then were called) would receive an adequate education. The commission decided that no child suspected of retardation should be placed in a special class for children with mental retardation without first being given an examination "from which it could be certified that because of the state of his intelligence, he was unable to profit, in an average measure, from the instruction given in the ordinary schools" (Binet & Simon, 1916a, p. 9).

Binet and Simon devised a test based on a conception of intelligence very different from Galton's and Cattell's. They viewed judgment as central to intelligence. At the same time, they viewed Galton's tests as ridiculous. They cited Helen Keller as an example of someone who was very intelligent but who would have performed terribly on Galton's tests.

Binet and Simon's (1916a) theory of intelligent thinking in many ways foreshadowed later research on the development of metacognition (e.g., Brown & DeLoache, 1978; Flavell & Wellman, 1977; Mazzoni & Nelson, 1998). According to Binet and Simon (1916b), intelligent thought comprises three distinct elements: direction, adaptation, and control. Direction consists in knowing what has to be done and how it is to be accomplished. When we are required to add three numbers, for example, we give ourselves a series of instructions on how to proceed, and these instructions form the direction of thought.

Adaptation refers to one's selection and monitoring of one's strategy during task performance. For example, in adding to numbers, one fifirst needs to decide on a strategy to add the numbers. As we add, we need to check (monitor) that we are not repeating the addition of any of the digits we already have added.

Control is the ability to criticize one's own thoughts and actions. This ability often occurs beneath the conscious level. If one notices that the sum one attains is smaller than either number (if the numbers are positive), one recognizes the need to add the numbers again, as there must have been a mistake in one's adding. Binet and Simon (1916b) distinguished between two types of intelligence: ideational intelligence and instinctive intelligence. *Ideational intelligence* operates by means of words and ideas. It uses logical analysis and verbal reasoning. *Instinctive intelligence* operates by means of feeling. It refers not to the instincts attributed to animals and to simple forms of human behavior but to lack of logical thinking. This twoprocess kind of model adumbrates many contemporary models of thinking (e.g., Evans, 1989; Sloman, 1996), which make similar distinctions.

What are some examples of the kinds of problems found on a Binet-based test (e.g., Terman & Merrill, 1937, 1973; R. L. Thorndike, Hagen, & Sattler, 1986)? In one version 2-year-olds are given a three-hole form board and required to place circular, square, and triangular pieces into appropriate indentations on it. Another test requires children to identify body parts on a paper doll. Six years later, by age 8, the character of the test items changes considerably. By age 8, the tests include vocabulary, which requires children to defifine words; verbal absurdities, which requires recognition of why each of a set of statements is foolish; similarities and differences, which requires children to say how each of two objects is the same as and different from the other; and comprehension, which requires children to solve practical problems of the sort encountered in everyday life. At age 14, there is some overlap in kinds of tests with age 8, as well as some different kinds of tests. For example, in an induction test, the experimenter makes a notch in an edge of some folded paper and asks participants how many holes the paper will have when it is unfolded. On a reasoning test, participants need to solve arithmetic word problems. Ingenuity requires individuals to indicate the series of steps that could be used to pour a given amount of water from one container to another.

The early Binet and Simon tests, like those of Cattell, soon were put to a test, in this case by Sharp (1899). Although her results were not entirely supportive, she generally accepted the view of judgment, rather than psychophysical processes, as underlying intelligence. Most subsequent researchers have accepted this notion as well.

Evaluation

Binet’s work was to have far more influence than Galton’s. Binet set many trends that were to be influential even up to the present day.

First, the kinds of test items Binet used are, for the most part, similar to those used in the present day. From the standpoint of modern test constructors, Binet “largely got it right.” Indeed, a current test, the fourth edition of the Stanford-Binet Intelligence Scale (R. L. Thorndike, Hagen, & Sattler, 1986) is a direct descendant of the Binet test. The Wechsler tests (e.g., Wechsler, 1991), although somewhat different in their conceptualization, owe a great deal to the conceptualization and tests of Binet.

Second, Binet grounded his tests in competencies that are central to schooling and perhaps less central to the world of adult work. Such grounding made sense, given the school based mission with which Binet was entrusted. Although intelligence-test scores correlate both with school grades and with work performance, their correlation with school grades is substantially higher, and they correlate better with job training performance than with work performance (see reviews in Mackintosh, 1998; Wagner, 2000).

Third, intelligence tests continue today, as in Binet’s time, to be touted as serving a protective function. The goal of Binet’s test was to protect children from being improperly classified in school. Today, test users point out how test scores can give opportunities to children who otherwise would not get them. For example, children from lower-level or even middle-level socioeconomic class backgrounds who would not be able to pay for certain kinds of schooling may receive admissions or scholarships on the basis of test scores.

At the same time, there is a dialectic in action here, whereby opponents of testing, or at least of certain kinds of testing, argue that the conventional tests do more damage than good (Gardner, 1983; Sacks, 1999), taking away opportunities rather than providing them to many children. An important aspect of Binet’s theory has been lost to many. This was Binet’s belief that intelligence is malleable and could be improved by “mental orthopedics.” To this day, many investigators are interested in raising levels of mental functioning (see review by Grotzer & Perkins, 2000). But many other investigators, even those who use Binet-based tests, question whether intelligence is malleable in any major degree (e.g., Jensen, 1969, 1998).

MODELS OF THE NATURE OF INTELLIGENCE

A number of different types of models have been proposed to characterize intelligence. What are the main models, and how are they similar to and different from one another?

Psychometric Models

The early efforts of intelligence theorists largely built upon the Binetian school of thought rather than the Galtonian school of thought. The most influential theorist historically, and perhaps even into the present, was also among the first, a British psychologist named Charles Spearman.

Spearman's Two-Factor Theory

Spearman (1904, 1927) proposed a two-factor theory of intelligence, a theory that is still very much alive and well today (e.g., Brand, 1996; Jensen, 1998). The theory posits a general factor (*g*) common to all tasks requiring intelligence and one specific factor (*s*) unique to each different type of task. Thus, there are two types of factors rather than, strictly speaking, two factors.

Spearman (1904) got this idea as a result of looking at data processed by a statistical technique of his own invention, namely, *factor analysis,* which attempts to identify latent sources of individual (or other) differences that underlie observed sources of variation in test performance. Spearman observed that when he factor-analyzed a correlation matrix, the two kinds of factors appeared—the general factor common to all of the tests and the specifific factors unique to each particular test.

Spearman (1927) admitted to not being sure what the psychological basis of *g* is but suggested that it might be mental energy (a term that he never defined very clearly). Whatever it was, it was a unitary and primary source of individual differences in intelligence-test performance.

The Theories of Bonds and of Connections

Theory of Bonds.

Spearman's theory was soon challenged and continues to be challenged today (e.g., Gardner, 1983; R. J. Sternberg, 1999b). One of Spearman's chief critics was British psychologist Sir Godfrey Thomson, who accepted Spearman's statistics but not his interpretation. Thomson (1939) argued that it is possible to have a general psychometric factor in the absence of any kind of general ability. In particular, he argued that *g* is a statistical reality but a psychological artifact. He suggested that the general factor might result from the working of an extremely large number of what he called *bonds*, all of which are sampled simultaneously in intellectual tasks. Imagine, for example, that each of the intellectual tasks found in Spearman's and others' test batteries requires certain mental skills. If each test samples all of these mental skills, then their appearance will be perfectly correlated with each other because they always cooccur. Thus, they will give the appearance of a single general factor when in fact they are multiple.

Although Thomson did not attempt to specify exactly what the bonds might be, it is not hard to speculate on what some of these common elements might be. For example, they might include understanding the problems and responding to them.

Theory of Connections.

Thorndike, Bregman, Cobb, and Woodyard (1926) proposed a quite similar theory, based on Thorndike's theory of learning. They suggested that in their deeper nature 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.* 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. (p. 415) According to this theory, then, learned connections, similar to Thomson's bonds, are what underlie individual differences in intelligence.

Thurstone's Theory of Primary Mental Abilities

Louis L. Thurstone, like Spearman, was an ardent advocate of factor analysis as a method of revealing latent psychological structures underlying observable test performances. Thurstone (1938, 1947) believed, however, that it was a mistake to leave the axes of factorial solutions unrotated. He believed that the solution thus obtained was psychologically arbitrary. Instead, he suggested rotation to what he referred to as *simple structure,* which is designed to clean up the columns of a factor pattern matrix so that the factors display either relatively high or low loadings of tests on given factors rather than large numbers of moderate ones. Using simple-structure rotation, Thurstone and Thurstone (1941) argued for the existence of seven primary mental abilities.

1. *Verbal comprehension*—the ability to understand verbal material. This ability is measured by tests such as vocabulary and reading comprehension.

2. *Verbal flfluency*—the ability involved in rapidly producing words, sentences, and other verbal material. This ability is measured by tests such as one that requires the examinee to produce as many words as possible in a short amount of time beginning with a certain letter.

3. *Number*—the ability to compute rapidly. This ability is measured by tests requiring solution of numerical arithmetic problems and simple arithmetic word problems.

4. *Memory*—the ability to remember strings of words, letters, numbers, or other symbols or items. This ability is measured by serial- or free-recall tests.

5. *Perceptual speed*—the ability rapidly to recognize letters, numbers, or other symbols. This ability is measured by proofreading tests, or by tests that require individuals to cross out a given letter (such as *A*) in a string of letters.

6. *Inductive reasoning*—the ability to reason from the specifific to the general. This ability is measured by tests such as letters series ("What letter comes next in the following series? b, d, g, k, ...") and number series ("What number comes next in the following series? 4, 12, 10, 30, 28, 84, . . .").

7. *Spatial visualization*—the ability involved in visualizing shapes, rotations of objects, and how pieces of a puzzle would fifit together. This ability is measured by tests that require mental rotations or other manipulations of geometric objects.

The argument between Spearman and Thurstone was not resoluble on mathematical grounds, simply because in exploratory factor analysis, any of an infifinite number of rotations of axes is acceptable. As an analogy, consider axes used to understand world geography (Vernon, 1971). One can use lines of longitude and latitude, but really any axes at all could be used, orthogonal or oblique, or even axes that serve different functions, such as in polar coordinates. The locations of points, and the distances between them, do not change in Euclidean space as a result of how the axes are placed. Because Thurstone's primary mental abilities are intercorrelated, Spearman and others have argued that they are nothing more than varied manifestations of *g:* Factor-analyze these factors, and a general factor will emerge as a second-order factor. Thurstone, of course, argued that the primary mental abilities were more basic. Such arguments became largely polemical because there really neither was nor is any way of resolving the debate in the terms in which it was presented. Some synthesis was needed for the opposing thesis of *g* versus the antithesis of primary mental abilities.

Hierarchical Theories

The main synthesis to be proposed was to be hierarchical theories—theories that assume that abilities can be ordered in terms of levels of generality. Rather than arguing which abilities are more fundamental, hierarchical theorists have argued that all of the abilities have a place in a hierarchy of abilities from the general to the specifific.

Holzinger's Bifactor Theory

Holzinger (1938) proposed a bifactor theory of intelligence, which retained both the general and specific factors of Spearman but also permitted group factors such as those found in Thurstone's theory. Such factors are common to more than one test but not to all tests. This theory helped form the basis for other hierarchical theories that replaced it.

Burt's Theory

Sir Cyril Burt (1949), known primarily for this widely questioned work on the heritability of intelligence, suggested that a five-level hierarchy would capture the nature of intelligence. At the top of Burt's hierarchy was "the human mind."

At the second level, the "relations level," are *g* and a practical factor. At the third level are associations, at the fourth level is perception, and at the fifth level is sensation. This model has not proven durable and is relatively infrequently cited today.

Vernon's Theory of Verbal : Educational and Spatial : Mechanical Abilities

A more widely adopted model has been that of Vernon (1971), which proposes the general factor, *g*, at the top of the hierarchy. Below this factor are two group factors, *v:ed* and *k:m*. The former refers to verbal-educational abilities of the kinds measured by conventional test of scholastic abilities.

The latter refers to spatial-mechanical abilities (with *k* perhaps inappropriately referring to the nonequivalent term *kinesthetic*).

Cattell's Theory of Fluid and Crystallized Abilities

More widely accepted than any of the previous theories is that of Raymond Cattell (1971), which is somewhat similar to Vernon's theory. This theory proposes general ability at the top of the hierarchy and two abilities immediately beneath it, fluid ability, or *gf* , and crystallized ability, or *gc*. Fluid ability is the ability to think flexibly and to reason abstractly. It is measured by tests such as number series and figural analogies. Crystallized ability is the accumulated knowledge base one has developed over the course of one's life as the result of the application of fluid ability. It is measured by tests such as vocabulary and general information.

More recent work has suggested that fluid ability is extremely difficult to distinguish statistically from general ability (Gustafsson, 1984, 1988). Indeed, the tests used to measure fluid ability are often identical to the tests used to measure what is supposed to be pure *g*. An example of such a test would be the Raven Progressive Matrices (Raven, Court, & Raven, 1992), which measures people's ability to fill in a missing part of a matrix comprising abstract figural drawings.

Horn (1994) has greatly expanded upon the hierarchical theory as originally proposed by Cattell. Most notably, he has suggested that *g* can be split into three more factors nested under fluid and crystallized abilities. These three other factors are visual thinking (*gv*), auditory thinking (*ga*), and speed (*gs*). The visual thinking factor is probably closer to Vernon's *k:m* factor than it is to the fluid ability factor.

Carroll's Three-Stratum Theory

Today, perhaps the most widely accepted hierarchical model is one proposed by Carroll (1993) that is based on the reanalysis of (more than 450) data sets from the past. At the top of the hierarchy is general ability; in the middle of the hierarchy are various broad abilities, including fluid and crystallized intelligence, learning and memory processes, visual and auditory perception, facile production, and speed. At the bottom of the hierarchy are fairly specific abilities.

Guilford's Structure-of-Intellect Model

Although many differential theorists followed the option of proposing a hierarchical model, not all did. J. P. Guilford (1967, 1982; Guilford & Hoepfner, 1971) proposed a model with 120 distinct abilities (increased to 150 in 1982 and to 180 in later manifestations). The basic theory organizes abilities along three dimensions: operations, products, and contents. In the best-known version of the model, there are five operations, six products, and four contents. The five operations are cognition, memory, divergent production, convergent production, and evaluation. The six products are units, classes, relations, systems, transformations, and implications. The four contents are figural, symbolic, semantic, and behavioral. Because these dimensions are completely crossed with each other, they yield a total of 5 6 4 or 120 different abilities. For example, inferring a relation in a verbal analogy (such as the relation between BLACK and WHITE in BLACK : WHITE :: HIGH : LOW) would involve cognition of semantic relations. Guilford's model has not fared well psychometrically.

Horn and Knapp (1973) showed that random theories could generate support equal to that obtained by Guilford's model when the same type of rotation was used that Guilford used— so-called "Procrustean rotation." Horn (1967) showed that equal support could be obtained with Guilford's theory, but with data generated randomly rather than with real data.

These demonstrations do not prove the model wrong: They show only that the psychometric support that Guilford claimed for his model was not justified by the methods he used.

Guttman's Radex Model

The last psychometric model to be mentioned is one proposed by Louis Guttman (1954). The model is what Guttman referred to as a radex, or radial representation of complexity. The radex consists of two parts. The first part is what Guttman refers to as a simplex. If one imagines a circle, then the simplex refers to the distance of a given point (ability) from the center of the circle. The closer a given ability is to the center of the circle, the more central that ability is to human intelligence. Thus, *g* could be viewed as being at the center of the circle, whereas the more peripheral abilities such as perceptual speed would be nearer to the periphery of the circle. Abilities nearer to the periphery of the circle are viewed as being constituents of abilities nearer the center of the circle, so the theory has a hierarchical element.

The second part of the radex is called the circumplex. It refers to the angular orientation of a given ability with respect to the circle. Thus, abilities are viewed as being arranged around the circle, with abilities that are more highly related (correlated) nearer to each other in the circle. Thus, the radex functions through a system of polar coordinates. Snow, Kyllonen, and Marshalek (1984) used nonmetric multidimensional scaling on a Thurstonian type of test to demonstrate that the Thurstonian primary mental abilities actually could be mapped into a radex.

Evaluation

Psychometric theories of intelligence have been enormously influential, particularly in North America and in the United Kingdom. In many respects, they have served the field well. First, they have provided a zeitgeist for three generations of researchers. Second, they have provided a systematic means for studying individual differences. Arguably, no other paradigm has provided any means that has been nearly as systematic or, really, successful in so many respects. Third, the theories cross well between theory and application. Few theories have proven to have as many and as diverse practical applications. Finally, they have provided a model for how theory and measurement can evolve in synchrony.

At the same time, there have been problems with the differential approach. First, although factor analysis, as a method, is neither good nor bad, it has frequently been subject to misuse (Horn & Knapp, 1973; Humphreys, 1962; McNemar, 1951). Second, factor analyses have sometimes been not so much misintepreted as overinterpreted. What one gets out of a factor analysis is simply a psychometric transformation of what one puts in. It is possible to support many different possible theories by choosing one's tests with a certain goal in mind. The resulting factors simply reflect the choice of tests and their interrelationships. Third, in exploratory factor analysis, the rotation issue has proven to be a thorny one. Any rotation is mathematically correct and equivalent in Euclidean space. Arguments over which theory is correct often have boiled down to little more than arguments over which rotation is psychologically more justified. But no adequate basis has been found for supporting one rotation as psychologically preferred over all others. Fifth and finally, the whole issue of deriving a theory of intelligence from patterns of individual differences has never received fully adequate examination by differential psychologists. Evolutionary theorists (e.g., Pinker, 1997; see R. J. Sternberg & Kaufman, 2001) would argue that intelligence needs to be understood in terms of commonalities, not differences. Of course, experimental psychologists have made the same claim for many decades, preferring to view individual differences as noise in their data. Perhaps the best solution is some kind of synthesis, as recommended by Cronbach (1957). Jean Piaget, disheartened with his observations from work in Binet's laboratory, provided a synthesis of sorts. He combined measurement with a more cognitive framework for understanding intelligence.

INTELLIGENCE AS ARISING FROM COGNITIVE STRUCTURES AND PROCESSES

Cognitive Structures

Piaget (1952, 1972), among others, has staked out an alternative position to the differential one. Piaget, who was never very interested in individual differences, viewed intelligence as arising from cognitive schemas, or structures that mature as a function of the interaction of the organism with the environment.

Equilibration

Piaget (1926, 1928, 1952, 1972), like many other theorists of intelligence, recognized the importance of adaptation to intelligence.

Indeed, he believed adaptation to be its most important principle. In adaptation, individuals learn from the environment and learn to address changes in the environment. Adjustment consists of two complementary processes: assimilation and accommodation. *Assimilation* is the process of absorbing new information and fifitting it into an already existing cognitive structure about what the world is like. The complementary process, *accommodation*, involves forming a new cognitive structure in order to understand information. In other words, if no existing cognitive structure seems adequate to understand new information, a new cognitive structure must be formed through the accommodation process.

The complementary processes of assimilation and accommodation, taken together in an interaction, constitute what Piaget referred to as equilibration. *Equilibration* is the balancing of the two, and it is through this balance that people either add to old schemas or form new ones. A *schema*, for Piaget, is a mental image or action pattern. It is essentially a way of organizing sensory information. For example, we have schemas for going to the bank, riding a bicycle, eating a meal, visiting a doctor's office, and the like.

Stages of Intellectual Development

Piaget (1972) suggested that the intelligence of children matures through four discrete stages, or periods of development. Each of these periods builds upon the preceding one, so that development is essentially cumulative.

The first period is the *sensorimotor period*, which occupies birth through roughly 2 years of age. By the end of the sensorimotor period, the infant has started to acquire object permanence, or the realization that objects can exist apart from him or herself. In early infancy, the infant does not ascribe a separate reality to objects. Thus, if a toy is hidden under a pillow or behind a barrier, the infant will not search for the toy because as far as he or she is concerned, it no longer exists when it goes out of sight. By the end of the period, the infant knows that a search will lead to finding the object.

The second period is the *preoperational period,* which emerges roughly between ages 2 and 7. The child is now beginning to represent the world through symbols and images, but the symbols and images are directly dependent upon the immediate perception of the child. The child is still essentially egocentric: He or she sees objects and people only from his or her own point of view. Thus, to the extent that thinking takes place, it is egocentric thinking.

The third period is the *concrete-operational period,* which occupies roughly ages 7 through 11. In this period, the child is able to perform concrete mental operations. Thus, the child now can think through sequences of actions or events that previously had to be enacted physically. The hallmark of concrete-operational thought is reversibility. It now is possible for the child to reverse the direction of thought. The child comes to understand, for example, that subtraction is the reverse of addition and division is the reverse of multiplication. The child can go to the store and back home again or trace out a route on a map and see the way back. The period is labeled as one of "concrete" operations because operations are performed for objects that are physically present. A major acquisition of the period is conservation, which involves a child's recognizing that objects or quantities can remain the same despite changes in their physical appearance. Suppose, for example, that a child is shown two glasses, one of which is short and fat and the other of which is tall and thin. If a preoperational child watches water poured from the short, fat glass to the tall, thin one, he or she will say that the tall, thin glass has more water than the short, fat one had. But the concrete-operational child will recognize that the quantity of water is the same in the new glass as in the old glass, despite the change in physical appearance.

The period of *formal operations* begins to evolve at around 11 years of age and usually will be fairly fully developed by 16 years of age, although some adults never completely develop formal operations. In the period of formal operations, the child comes to be able to think abstractly and hypothetically, not just concretely. The individual can view a problem from multiple points of view and can think much more systematically than in the past. For example, if asked to provide all possible permutations of the numbers 1, 2, 3, and 4, the child can now implement a systematic strategy for listing all of these permutations. In contrast, the concrete operational child will have essentially listed permutations at random, without a systematic strategy for generating all of the possible permutations. The child can now think scientifically and use the hypothetico-deductive method to generate and test hypotheses.

Vygotsky and Feuerstein's Theories

Whereas Piaget has emphasized primarily biological maturation in the development of intelligence, other theorists interested in structures, such as Vygotsky (1978) and Feuerstein (1979), have emphasized more the role of interactions of individuals with the environment. Vygotsky suggested that basic to intelligence is *internalization*, which is the internal reconstruction of an external operation. The basic notion is that we observe those in the social environment around us acting in certain ways and we internalize their actions so that they become a part of ourselves. Vygotsky (1978) gave as an example of internalization the development of pointing. He suggested that, initially, pointing is nothing more than an unsuccessful attempt to grasp something. The child attempts to grasp an object beyond his reach and, initially, is likely to fail. When the mother sees the child attempting to grasp an object, she comes to his aid and is likely to point to the object. He thereby learns to do the same. Thus, the child's unsuccessful attempt engenders a reaction from the mother or some other individual, which leads to his being able to perform that action. Note that it is the social mediation rather than the object itself that provides the basis for the child's learning to point.

Vygotsky also proposed the important notion of a *zone of proximal development,* which refers to functions that have not yet matured but are in the process of maturation. The basic idea is to look not only at developed abilities but also at abilities that are developing. This zone is often measured as the difference between performance before and after instruction. Thus, instruction is given at the time of testing to measure the individual's ability to learn in the testing environment (Brown & French, 1979; Feuerstein, 1980; Grigorenko & Sternberg, 1998). The research suggests that tests of the zone of proximal development tap abilities not measured by conventional tests.

Related ideas have been proposed by Feuerstein (1979, 1980). Feuerstein has suggested that much of intellectual development derives from the mediation of the environment by the mother or other adults. From Feuerstein's point of view, parents serve an important role in development not only for the experiences with which they provide children but also for the way they help children understand these experiences.

For example, what would be important would be not so much encouraging children to watch educational television or taking children to museums but rather helping children interpret what they see on television or in museums.

Evaluation

By any standard, Piaget's contribution to the study of intelligence was profound. First, his theory stands alone in terms of its comprehensiveness in accounting for intellectual development. There is no competition in this respect. Second, even the many individuals who have critiqued Piaget's work havehonored the work by deeming it worthy of criticism. To the extent that a theory's value is heuristic, in its giving way to subsequent theories, Piaget's work is almost without peer. And much research today, especially in Europe, continues in the tradition of Piaget. Neo-Piagetians, although they have changed many of the details, still build upon many Piagetian theoretical ideas and tasks for studying development. Third, even the most ardent critics of Piaget would concede that many of his ideas were correct. Many of those ideas, such as of centration, conservation, and equilibration, remain alive today in a wide variety of forms. Fourth, Piaget provided an enormous database for developmental psychologists to dealwith today as earlier. Replications generally have proven to be successful (Siegler, 1996). Yet the theory of Piaget has not stood the test of time without many scars. Consider some of the main ones.

First, Piaget’s interpretations of data have proven to be problematical in many different respects. The list of such critiques is very long. For example, there is evidence that infants achieve object permanence much earlier than Piaget had thought (e.g., Baillargeon, 1987; Bowers, 1967, 1974; Cornell, 1978). There also is evidence that conservation begins earlier than Piaget suspected (Au, Sidle, & Rollins, 1993). As another example, diffificulties that Piaget attributed to reasoning appear in some instances actually to have been due to memory (e.g., Bryant & Trabasso, 1971).

Second, it now appears that children often failed Piagetian tasks not because they were unable to do them but because they did not understand the task in the way the experimenter intended. The research of Piaget points out how important it is to make sure one understands a problem not only from one’s own point of view as experimenter but also from the child’s point of view as participant. For example, being asked whether a collection of marbles contains more blue marbles or more marbles can be confusing, even to an adult.

Third, many investigators today question the whole notion of stages of development (e.g., Brainerd, 1978; Flavell, 1971). Piaget fudged a bit with the concept of *horizontal dé- calage,* or nonsimultaneous development of skills within a given stage across domains, but many investigators believe that development is simply much more domain specific than Piaget was willing to admit (e.g., Carey, 1985; Keil, 1989). As another example, children master different kinds of conservation problems at different ages, with the differences appearing in a systematic fashion (Elkind, 1961; Katz & Beilin, 1976; S. A. Miller, 1976), with conservation of number appearing before conservation of solid quantity, and conservation of solid quantity before that of weight.

Fourth, many investigators have found Piaget's theory to characterize children's competencies more than their performance (e.g., Green, Ford, & Flamer, 1971). Indeed, Piaget (1972) characterized his model as a competency model. For this reason, it may not be optimally useful in characterizing what children are able to do on a day-to-day basis.

Fifth, although Piaget believed that cognitive development could not be meaningfully accelerated, the evidence suggests the contrary (Beilin, 1980). Piaget probably took too strong a position in this regard.

Finally, some have questioned the emphasis Piaget placed on logical and scientifific thinking (e.g., R. J. Sternberg, 1990b). People often seem less rational and more oriented toward heuristics than Piaget believed (Gigerenzer, Todd, & ABC Research Group, 1999).

Vygotsky's theory is, at the turn of the century, more in vogue than Piaget's. It better recognizes the important role of the social-cultural environment in intellectual development. And it also suggests how conventional tests may fail to unearth developing intellectual functions that give children added potential to succeed intellectually. Vygotsky's theory is rather vague, however, and much of the recent development has gone considerably beyond anything Vygotsky proposed. Perhaps if Vygotsky had not died tragically at an early age (38), he would have extensively amplified on his theory.

Cognitive Processes

Arelated position is that of cognitive theorists (e.g.,Anderson, 1983; G. A. Miller, Galanter, & Pribram, 1960; Newell & Simon, 1972), who seek to understand intelligence in terms of the processes of human thought and also the architecture that holds together these processes. These theorists may use the software of a computer as a model of the human mind, or in more recent theorizing, use the massively parallel operating systems of neural circuitry as a model (e.g., Rumelhart, McClelland, & PDP Research Group, 1986). Much of the history of this fifield is relatively recent, simply because much of the "early" development of the field has occurred in recent times. The field today, for example, has advanced quite far beyond where it was 30 years ago. At the same time, the origins of the field go back to early in the twentieth century and even further, depending upon how broad one is in labeling work as related to this approach.

The Origins of the Process-Based Approach in Spearman's Principles of Cognition

Although some psychologists in the nineteenth century were interested in information processing (e.g., Donders, 1868/ 1869), the connection between information processing and intelligence seems fifirst to have been explicitly drawn by Charles Spearman (1923), the same individual known for initiating serious psychometric theorizing about intelligence.

Spearman (1923) proposed what he believed to be three fundamental qualitative principles of cognition. The fifirst, *apprehension of experience,* is what today might be called the encoding of stimuli (see R. J. Sternberg, 1977). It involves perceiving the stimuli and their properties. The second principle, *eduction of relations,* is what today might be labeled inference. It is the inferring of a relation between two or more concepts. The third principle, *eduction of correlates,* is what today might be called application. It is the application of an inferred rule to a new situation. For example, in the analogy WHITE : BLACK

:: GOOD : ?, apprehension of experience would involve reading each of the terms. Eduction of relations would involve inferring the relation between WHITE and BLACK. And eduction of correlates would involve applying the inferred relation to complete the analogy with *BAD*. Tests that measure these attributes without contamination from many other sources, such as the Raven Progressive Matrices tests, generally provide very good measures of psychometric *g*.

The Cognitive-Correlates Approach

Lee Cronbach (1957) tried to revive interest in the cognitive approach with an article on “the two disciplines of scientific psychology,” and efforts to revive this approach in the 1960s proceeded by fifits and starts. But serious revival can probably be credited in large part to the work of Earl Hunt. Hunt (1978, 1980; Hunt et al., 1973; Hunt, Lunneborg, & Lewis, 1975) was the originator of what has come to be called the *cognitive-correlates approach* to integrating the study of cognitive processing with the study of intelligence (Pellegrino & Glaser, 1979).

The proximal goal of this research is to estimate parameters representing the durations of performance for information processing components constituting experimental tasks commonly used in the laboratories of cognitive psychologists. These parameters are then used to investigate the extent to which cognitive components correlate across participants with each other and with scores on psychometric measures commonly believed to measure intelligence, such as the Raven Progressive Matrices tests. Consider an example. In one task—the Posner and Mitchell (1967) letter matching task—participants are shown pairs of letters such as “A A” or “A a.” After each pair, they are asked to respond as rapidly as possible to one of two questions: “Are the letters a physical match?” or “Are the letters a name match?” Note that the first pair of letters provides an affirmative answer to both questions, whereas the second pair of letters provides an affirmative answer only to the second of the two questions. That is, the first pair provides both a physical and a name match, whereas the second pair provides a name match only.

The goal of such a task is to estimate the amount of time a given participant takes to access lexical information—letter names—in memory. The physical-match condition is included to subtract out (control for) sheer time to perceive the letters and respond to questions. The difference between name and physical match time thus provides the parameter estimate of interest for the task. Hunt and his colleagues found that this parameter and similar parameters in other experimental tasks typically correlate about .3 with scores on psychometric tests of verbal ability. The precise tasks used in such research have varied. The letter-matching task has been a particularly popular one, as has been the short-term memory-scanning task originally proposed by S. Sternberg (1969). Other researchers have preferred simple and choice reaction time tasks (e.g., Jensen, 1979, 1982). Most such studies have been conducted with adults, but some have been conducted developmentally with children of various ages (e.g., Keating & Bobbitt, 1978).

The Cognitive-Components Approach

An alternative approach has come to be called the *cognitivecomponents approach* (Pellegrino & Glaser, 1979). In this approach, participants are tested in their ability to perform tasks of the kinds actually found on standard psychometric tests of mental abilities—for example, analogies, series completions, mental rotations, and syllogisms. Participants typically are timed, and response time is the principal dependent variable, with error rate and pattern-of-response choices serving as further dependent variables. This approach was suggested by R. J. Sternberg (1977; see also Royer, 1971). The proximal goal in this research is, first, to formulate a model of information processing in performance on the types of tasks found in conventional psychometric tests of intelligence. Second, it is to test the model at the same time as parameters for the model are estimated. Finally, it is to investigate the extent to which these components correlate across participants with each other and with scores on standard psychometric tests. Because the tasks that are analyzed are usually taken directly from psychometric tests of intelligence or are very similar to such tasks, the major issue in this kind of research is not whether there is any correlation at all between cognitive task and psychometric test scores. Rather, the issue is one of isolating the locus or loci of the correlations that are obtained. One seeks to discover which components of information processing are the critical ones from the standpoint of the theory of intelligence (Carroll, 1981; Pellegrino & Glaser, 1979, 1980, 1982; Royer, 1971; R. J. Sternberg, 1977, 1980, 1983; R. J. Sternberg & Gardner, 1983).

Consider the analogies task mentioned above. The participant might be presented with an analogy such as WHITE : BLACK :: GOOD : (A) BAD, (B) BETTER. The task is to choose the better of the two response options as quickly as possible. Cognitive-components analysis might extract a number of components from the task, using an expanded version of Spearman’s theory (R. J. Sternberg, 1977). These components might include (a) the time to *encode* the stimulus terms, (b) the time to *infer* the relation between WHITE and BLACK, (c) the time to *map* the relation from the fifirst half of the analogy to the second, (d) the time to *apply* the inferred relation from GOOD to each of the answer options, (e) the time to *compare* the two response options, (f) the time to *justify* BAD as the preferable option, and (g) the time to *respond* with (A).

The Cognitive-Training Approach

The goal of the *cognitive-training approach* is to infer the components of information processing from how individuals perform when they are trained. According to Campione, Brown, and Ferrara (1982), one starts with a theoretical analysis of a task and a hypothesis about a source of individual differences within that task. It might be assumed, for example, that components A, B, and C are required to carry out Task X and that less able children do poorly because of a weakness in component A. To test this assertion, one might train less able participants in the use of A and then retest them on X. If performance improves, the task analysis is supported. If performance does not improve, then either A was not an important component of the task, participants were originally efficient with regard to A and did not need training, or the training was ineffective (see also Belmont & Butterfield, 1971; Belmont, Butterfield, & Ferretti, 1982; Borkowski & Wanschura, 1974).

The Cognitive-Contents Approach

In the *cognitive-contents approach*, one seeks to compare the performances of experts and novices in complex tasks such as physics problems (e.g., Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Larkin, McDermott, Simon, & Simon, 1980), the selection of moves and strategies in chess and other games (Chase & Simon, 1973; DeGroot, 1965; Reitman, 1976), and the acquisition of domain-related information by groups of people at different levels of expertise (Chiesi, Spilich, & Voss, 1979). The notion underlying such research can be seen as abilities being forms of developing expertise (R. J. Sternberg, 1998). In other words, the experts have developed high levels of intellectual abilities in particular domains as results of the development of their expertise. Research on expert-novice differences in a variety of task domains suggests the importance of the amount and form of information storage in long-term memory as key to expert-novice differences.

Evaluation

The information-processing approach to understanding intelligence has been very productive in helping to elucidate the nature of the construct. First, it has been uniquely successful in identifying processes of intelligent thinking. Second, it has not been bound to individual differences as a source of determining the bases of human intelligence. It can detect processes, whether or not they are shared across individuals. Third, it is the approach that seems most conducive to the use of conventional experimental methods of analysis, so that it is possible to gain more control in experimentation by the use of these methods than by the use of alternative methods. The approach has also had its weaknesses, though. First, in many cases, information-processing psychologists have not been terribly sensitive to individual differences. Second, information-processing psychologists often have been even less sensitive to contextual variables (see Neisser, 1976; R. J. Sternberg, 1997). Third, although information-processing analyses are not subject to the rotation dilemma, it is possible to have two quite different models that nevertheless account for comparable proportions of variation in the response-time or error-rate data, thereby making the models indistinguishable. In other words, difficulties in distinguishing among models can plague this approach every bit as much as they can plague psychometric models (Anderson, 1983). Finally, the approach simply never produced much in the way of useful tests. Even more than a quarter of a century after its initiation, the approach has little to show for itself by way of useful or at least marketable products. Perhaps this is because it never worked quite the way it was supposed to. For example, R. J. Sternberg (1977) and R. J. Sternberg and Gardner (1983) found that the individual parameter representing a regression constant showed higher correlations with psychometric tests of abilities than did parameters representing well-defined information-processing components.

BIOLOGICAL BASES OF INTELLIGENCE

Some theorists have argued that notions of intelligence should be based on biological notions, and usually, on scientific knowledge about the brain. The idea here is that the base of intelligence is in the brain and that behavior is interesting in large part as it elucidates the functioning of the brain. One of the earlier theories of brain function was proposed by Halstead (1951). Halstead suggested four biologically based abilities: (a) the integrative fifield factor (C), (b) the abstraction factor (A), (c) the power factor (P), and (d) the directional factor (D). Halstead attributed all four of these abilities primarily to the cortex of the frontal lobes. Halstead's theory became the basis for a test of cognitive functioning, including intellectual aspects (the Halstead-Reitan Neuropsychological Test Battery).

A more inflfluential theory, perhaps, has been that of Donald Hebb (1949). Hebb suggested the necessity of distinguishing among different intelligences. *Intelligence A* is innate potential. It is biologically determined and represents the capacity for development. Hebb described it as "the possession of a good brain and a good neural metabolism" (p. 294). *Intelligence B* is the functioning of the brain in which development has occurred. It represents an average level of performance by a person who is partially grown. Although some inference is necessary in determining either intelligence, Hebb suggested that inferences about intelligence A are far less direct than inferences about intelligence B. A further distinction could be made with regard to *Intelligence C*, which is the score one obtains on an intelligence test. This intelligence is Boring's intelligence as the tests test it. A theory with an even greater impact on the fifield of intelligence research is that of the Russian psychologist Alexander Luria (1973, 1980). Luria believed that the brain is a highly differentiated system whose parts are responsible for different aspects of a unifified whole. In other words, separate cortical regions act together to produce thoughts and actions of various kinds. Luria (1980) suggested that the brain comprises three main units. The fifirst, a unit of arousal, includes the brain stem and midbrain structures. Included within this first unit are the medulla, reticular activating system, pons, thalamus, and hypothalamus. The second unit of the brain is a sensori-input unit, which includes the temporal, parietal, and occipital lobes. The third unit includes the frontal cortex, which is involved in organization and planning. It comprises cortical structures anterior to the central sulcus. The most active research program based on Luria's theory has been that of J. P. Das and his colleagues (e.g., Das, Kirby, & Jarman, 1979; Das, Naglieri, & Kirby, 1994; Naglieri & Das, 1990, 1997). The theory as they conceive of it is referred to as PASS theory, referring to *planning, attention, simultaneous processing*, and *successive processing*. The idea is that intelligence requires the ability to plan and to pay attention. It also requires the ability to attend simultaneously to many aspects of a stimulus, such as a picture, or, in some cases, to process stimuli sequentially, as when one memorizes a string of digits to remember a telephone number. Other research and tests also have been based on Luria's theory (e.g., Kaufman & Kaufman, 1983).

An entirely different approach to understanding intellectual abilities has emphasized the analysis of hemispheric specialization in the brain. This work goes back to a finding of an obscure country doctor in France, Marc Dax, who in 1836 presented a little-noticed paper to a medical society meeting in Montpelier. Dax had treated a number of patients suffering from loss of speech as a result of brain damage. The condition, known today as aphasia, had been reported even in ancient Greece. Dax noticed that in all of more than 40 patients with aphasia, there had been damage to the left hemisphere of the brain but not the right hemisphere. His results suggested that speech and perhaps verbal intellectual functioning originated in the left hemisphere of the brain. Perhaps the most well-known fifigure in the study of hemispheric specialization is Paul Broca. At a meeting of the French Society of Anthropology, Broca claimed that a patient of his who was suffering a loss of speech was shown postmortem to have a lesion in the left frontal lobe of the brain. At the time, no one paid much attention. But Broca soon became associated with a hot controversy over whether functions, particular speech, are indeed localized in the brain. The area that Broca identified as involved in speech is today referred to as Broca's area. By

1864, Broca was convinced that the left hemisphere is critical for speech. Carl Wernike, a German neurologist of the late nineteenth century, identified language-deficient patients who could speak but whose speech made no sense. He also traced language ability to the left hemisphere, though to a different precise location, which now is known as Wernicke's area.

Nobel Prize–winning physiologist and psychologist Roger Sperry (1961) later came to suggest that the two hemispheres behave in many respects like separate brains, with the left hemisphere more localized for analytical and verbal processing and the right hemisphere more localized for holistic and imaginal processing. Today it is known that this view was an over simplification and that the two hemispheres of the brain largely work together (Gazzaniga, Ivry, & Mangun, 1998).

Evaluation

The biological approach has provided unique insights into the nature of intelligence. Its greatest advantage is its recognition that, at some level, the brain is the seat of intelligence. In modern times, and to a lesser extent in earlier times, it has been possible to pinpoint areas of the brain responsible for various functions. The approach is now probably among the most productive in terms of the sheer amount of research being generated.

The greatest weakness of the approach is not so much a problem of the approach as in its interpretation. Reductionists would like to reduce all understanding of intelligence to understanding of brain function, but it just will not work. If we want to understand how to improve the school learning of a normal child through better teaching, we are not going to find an answer in the foreseeable future through the study of the brain. Culture affects what kinds of behavior are viewed as more or less intelligent within a given cultural setting, but again, the biology of the brain will not settle the question of what behavior is considered intelligent within a given culture or why it is considered to be so.

Another weakness of the approach, or at least of its use, has been invalid inferences. Suppose one finds that a certain evoked potential is correlated with a certain cognitive response. All one really knows is that there is a correlation. The potential could cause the response, the response could cause the potential, or both could be based upon some higher-order factor. Yet, reports based on the biological approach often seem to suggest that the biological response is somehow causal (e.g., Hendrickson & Hendrickson, 1980). Useful though the biological approach may be, it always will need to be supplemented by other approaches.

CULTURE AND SOCIETY

A rather different position has been taken by more anthropologically oriented investigators. Modern investigators trace their work back at the very least to the work of Kroeber and Kluckhohn (1952), who studied culture as patterns of behavior acquired and transmitted by symbols. Much of the work in this approach, like that in the cognitive approach, is relatively recent.

The most extreme position is one of radical cultural relativism, proposed by Berry (1974), which rejects assumed psychological universals across cultural systems and requires the generation from within each cultural system of any behavioral concepts to be applied to it (the so-called *emic* approach). According to this viewpoint, therefore, intelligence can be understood only from within a culture, not in terms of views imposed from outside that culture (the so-called *etic* approach). Even in present times, psychologists have argued that the imposition of Western theories or tests on non Western cultures can result in seriously erroneous conclusions about the capabilities of individuals within those cultures (Greenfifield, 1997; R. J. Sternberg et al., 2000). Other theorists have taken a less extreme view. For example, Michael Cole and his colleagues in the Laboratory of Comparative Human Cognition (1982) argued that the radical position does not take into account the fact that cultures interact. Cole and his colleagues believe that a kind of conditional comparativism is important, so long as one is careful in setting the conditions of the comparison. Cole and his colleagues gave as an example a study done by Super (1976). Super found evidence that African infants sit and walk earlier than do their counterparts in the United States and Europe. But does such a finding mean that African infants are better walkers, in much the same way that North American psychologists have concluded that American children are better thinkers than African children (e.g., Herrnstein & Murray, 1994)? On the contrary, Super found that mothers in the culture he studied made a self-conscious effort to teach babies to sit and walk as early as possible. He concluded that the African infants are more advanced because they are specifically taught to sit and walk earlier and are encouraged through the provision of opportunities to practice these behaviors. Other motor behaviors were not more advanced. For example, infants found to sit and walk early were actually found to crawl later than did infants in the United States.

Evaluation

The greatest strength of cultural approaches is their recognition that intelligence cannot be understood fully outside its cultural context. Indeed, however common may be the thought processes that underlie intelligent thinking, the behaviors that are labeled as intelligent by a given culture certainly vary from one place to another, as well as from one epoch to another.

The greatest weakness of cultural approaches is their vagueness. They tend to say more about the context of intelligent behavior than they do about the causes of such behavior. Intelligence probably always will have to be understood at many different levels, and any one level in itself will be inadequate. It is for this reason, presumably, that systems models have become particularly popular in recent years. These models attempt to provide an understanding of intelligence at multiple levels.

SYSTEMS MODELS

The Nature of Systems Models

In recent times, systems models have been proposed as useful bases for understanding intelligence. These models seek to understand the complexity of intelligence from multiple points of view and generally combine at least two and often more of the models described above. For example, Gardner (1983, 1993, 1999) has proposed a theory of multiple intelligences, according to which intelligence is not just one thing but multiple things. According to this theory, there are 8 or possibly even 10 multiple intelligences—linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic interpersonal, intrapersonal, naturalist, and possibly existential and spiritual. R. J. Sternberg (1985, 1988, 1997, 1999b) has proposed a theory of successful intelligence, according to which intelligence can be seen in terms of various kinds of information-processing components combining in different ways to generate analytical, creative, and practical abilities. Ceci (1996) has proposed a bioecological model of intelligence, according to which intelligence is understood in the interaction between the biology of the individual and the ecology in which the individual lives. These theories are described in more detail in “Contemporary Theories of Intelligence”.

Evaluation

The complexity of systems models is both a blessing and a curse. It is a blessing because it enables such models to recognize the multiple complex levels of intelligence. It is a curse because the models become more difficult to test. Indeed, one of the most popular models, that of Gardner (1983), was proposed some time ago. But as of when this chapter is being written, there has not been even one empirical test of the model as a whole, scarcely a commendable record for a scientific theory. This record compares with thousands of predictive empirical tests of psychometric or Piagetian models and probably hundreds of tests of information processing models. R. J. Sternberg's (1997) triarchic theory has been predictively empirically tested numerous times (see, e.g., R. J. Sternberg et al., 2000), but because most of these tests have been by members of Sternberg's research group, the results cannot be considered definitive at this time.

CONCLUSION: RELATIONS AMONG THE VARIOUS MODELS OF THE NATURE OF INTELLIGENCE

There are different ways of resolving the conflicts among alternative models of the nature of intelligence.

Different Names

One way of resolving the conflicts is to use different names for different constructs. For example, some researchers stake their claim on a certain number of intelligences or intellectual abilities. Is intelligence, fundamentally, 1 important thing (Spearman, 1904), or 7 things (Gardner, 1983), or maybe 10 things (Gardner, 1999), or perhaps 120 things (Guilford, 1967), or even 150 or more things (Guilford, 1982)? Some might say that those who are splitters are actually talking of "talents" rather than intelligence, or that they are merely slicing the same "pie" everyone else is eating, but very thinly. Sometimes different names are used to reflect the same construct! For example, what once was the Scholastic Aptitude Test later became the Scholastic Assessment Test and still later became simply the SAT, an acronym perhaps belatedly asserted to stand for nothing in particular. The change in the name of the test points out how, over time and place, similar or even identical constructs can be given names in order to reflect temporally or spatially local sensibilities about what constitutes desirable or even acceptable terminology. Many similar efforts, such as referring to what usually is called *intelligence* as *cognitive development* (R. L. Thorndike, Hagen, & Sattler, 1986), point out the extent to which the history of intelligence is in part a battle over names.

In a sense, the history of the field of intelligence bifurcates. Some investigators, perhaps starting with Boring (1923), have suggested we define intelligence as what intelligence tests measure and get on with testing it; other investigators, such as Spearman (1904, 1927) and Thurstone (1938) view the battle over what intelligence is as determining what should be tested.

Fighting for "Truth"

A second response to the differences among theories has been for researchers to stake their ground and then slug it out in a perceived fight for the truth. Some of these battles became rather bitter. Underlying these battles was the notion that only one model or theory embedded under a model could be correct, and therefore the goal of research should be to figure out which one that is.

Dialectical Synthesis

A third response has been to seek some kind of dialectical synthesis among alternative models or theories embedded under these models. There have been different kinds of syntheses.

One Kind of Approach or Methodology Eventually Should Be Replaced by Another

Some investigators have argued that their approach is the best the field can do at the time, but that the approach later will be replaced. For example, Louis L. Thurstone suggested that factor analysis is useful in early stages of investigation, laboratory research, later on. In other words, the differential approach could be replaced by a more cognitively based one. Thurstone (1947), who was largely a psychometric theorist, argued that The exploratory nature of factor analysis is often not understood. Factor analysis has its principal usefulness at the borderline of intelligence. It is naturally superseded by rational formulations in terms of the science involved. Factor analysis is useful, especially in those domains where basic and fruitful concepts are essentially lacking and where crucial experiments have been difficult to conceive. . . . But if we have scientific intuition and sufficient ingenuity, the rough factorial map of a new domain will enable us to proceed beyond the exploratory factorial stage to the more direct forms of psychological experimentation in the laboratory. (p. 56)

Coexistence

Other investigators argued for coexistence. Charles Spearman, for example, had both a differential theory of intelligence (Spearman, 1927) and a cognitively based one (Spearman, 1923) (both of which were described earlier). Cronbach (1957) argued for the merger of the fields of differential and experimental psychology.

Synthetic Integration

Perhaps the best way to achieve a certain coherence in the field is to recognize that there is no one right "model" or "approach" and that different ones elucidate different aspects of a very complex phenomenon. Models such as the systems models are useful in attempting integrations, but they fall short in integrating all that we know about intelligence.

Eventually, the time may come when such large-scale integrations can be achieved in ways that are theoretically meritorious and empirically sound. In the meantime, it is likely that many different conceptions of intelligence will compete for the attention of the scientific as well as the lay public.