CHAPTER 10

THEORIES OF INTELLIGENCE

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To understand giftedness, and particularly intellectual giftedness, one must understand intelligence. But what is intelligence? In 1921, when the editors of the *Journal of Educational Psychology* asked 14 famous psychologists that question, the responses varied, but generally embraced two themes. First, intelligence involves the capacity to learn from experience. Second, it involves the ability to adapt to the surrounding environment. Sixty-five years later, 24 cognitive psychologists with expertise in intelligence research were asked the same question (Sternberg & Detterman, 1986). They, too, underscored the importance of learning from experience and adapting to the environment. They also broadened the definition to emphasize the importance of *metacognition*—people's understanding and control of their own thinking processes. Contemporary experts also more heavily emphasized the role of culture. They pointed out that what is considered intelligent in one culture may be considered less intelligent in another culture (Ang, Van Dyne, & Tan, 2011). To summarize, *intelligence* is the capacity to learn from experience, using metacognitive processes to enhance learning, and the ability to adapt to the surrounding environment; it may require different adaptations within different social and cultural contexts (Niu & Brass, 2011; Saklofske, van de Vijver, Oakland, Mpofu, & Suzuki, 2015; Sternberg, 2004).

According to the *Oxford English Dictionary,* the word *intelligence* entered our language in about the 12th century. Today, we can look up intelligence in numerous dictionaries, but most of us still have our own implicit ideas about what it means to be smart.

IMPORTANCE OF THE TOPIC

We are constantly using our implicit theories, or folk conceptions, of intelligence to judge other people. We need to understand what intelligence is and how we make judgments about it because we use our implicit (folk) theories in many social situations (e.g., when meeting people for the first time). We also use them when we describe people we know as being very smart or not so smart (Grigorenko et al., 2001; Sternberg, 1985b).

Within our implicit theories of intelligence, we also recognize that intelligence has somewhat different meanings in different contexts. A smart salesperson may show a different kind of intelligence than a smart neurosurgeon or a smart accountant. Each of them may show a different kind of intelligence than a smart choreographer, composer, athlete, or sculptor. Often, we use our implicit theories of intelligence to make assessments of intelligence. Is your mechanic smart enough to find and fix the problem in your car? Is your physician smart enough to find and treat your health problem? Is this attractive person smart enough to be your partner in life?

Implicit theories of intelligence may differ from one culture to another. For example, there is evidence that Chinese people in Taiwan include interpersonal and intrapersonal skills as part of their conception of intelligence (see Sternberg, 2004).

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Rural Kenyan conceptions of intelligence encompass moral, as well as cognitive, skills (Grigorenko et al., 2001). Therefore, what might count as a comprehensive assessment of intelligence could differ from one culture to another. Even within the United States, many people today have started viewing the emotional aspects of intelligence as important, in addition to the cognitive aspects of intelligence. *Emotional intelligence* is "the ability to perceive and express emotion, assimilate emotion in thought, understand and reason with emotion, and regulate emotion in the self and others" (Mayer, Salovey, & Caruso, 2000, p. 396; see also Chapter 38, this handbook). There is good evidence for the existence of some kind of emotional intelligence (Mayer, 2014), although the evidence is not conclusive. The concept of emotional intelligence has also become very popular in recent years (Goleman, Boyatzis, & McKee, 2013; Stein & Deonarine, 2015). Some evidence suggests that emotional intelligence is a strong predictor of successful adaptation to new environments (e.g., going to college or traveling to a foreign country) and of success in one's chosen field. A related concept is that of *social intelligence*, which is the ability to understand and interact with other people (Boyatzis, Gaskin, & Wei, 2015).

Further, there are a number of cultural differences in the definition of intelligence. These differences have led to a field of study within intelligence research that examines understanding of cultural differences in the definition of intelligence. This field explores what is termed *cultural intelligence* (Ang, Van Dyne, & Tan, 2011). This term is used to describe a person's ability to adapt to a variety of challenges in diverse cultures. Research also shows that personality variables are related to intelligence (DeYoung, 2011). Taken together, this evidence suggests that a comprehensive definition of intelligence incorporates many facets of intellect.

Explicit definitions of intelligence also frequently take on an assessment-oriented focus. In fact, some psychologists have been content to define intelligence as whatever it is that the tests measure (Boring, 1923). This definition, unfortunately, is circular: the nature of intelligence is what is tested, but what is tested must necessarily be determined by the nature of intelligence. Moreover, what different tests of intelligence measure is not always the same thing. Different tests measure somewhat different constructs (Naglieri, 2015; Pfeiffer, 2015). So it is not feasible to define intelligence by what tests measure, because they do not measure the same thing.

The bottom line is that in society, implicit theories dominate explicit ones. Most of our thinking about intelligence, and giftedness, is guided by informal folk concepts, not by formal psychological definitions. Even standardized testing is based on implicit theories, in large degree. For example, it used to be socially acceptable in schools to give IQ tests. Today, such tests are no longer viewed as acceptable, so IQ tests used are given other names: SAT, ACT, GRE, etc. Statistically, these tests measure largely the same thing as conventional IQ tests (Koenig, Frey, & Detterman, 2008), but it would be a bad business decision to call them "IQ tests." Therefore, in thinking about the intelligence of giftedness, we need to realize that we often are dealing with social constructions rather than formal scientific concepts.

HISTORICAL AND CONTEMPORARY PERSPECTIVES

Contemporary measurements of intelligence usually can be traced to one of two very different historical traditions. One tradition concentrated on lower-level, psychophysical abilities. These include sensory acuity, physical strength, and motor coordination. The other focused on higher-level, judgmental abilities. We traditionally describe these abilities as related to thinking, reasoning, and problem solving (Lohman & Lakin, 2011). For the most part, the tradition of Binet has dominated. Most tasks on IQ tests are tests of judgment, reasoning, problem solving, decision making, and knowledge (primarily of an academic kind). However, there sometimes are quite basic tasks as well, such as perceptual-speed measures that assess skills such as crossing *t*'s and dotting *i*'s.

Galton

Francis Galton, an English psychologist and statistician, believed that intelligence is a function of psychophysical abilities. For several years, Galton maintained a well-equipped laboratory where visitors could have themselves measured on a variety of psychophysical tests. These tests measured a broad range of psychophysical skills and sensitivities (e.g., weight discrimination, or the ability to notice small differences in the weights of objects; pitch sensitivity, or the ability to hear small differences between musical notes; physical strength; Galton, 1883). One of the many enthusiastic followers of Galton, Wissler (1901), attempted to detect links among the assorted tests. Wissler hoped such links would unify the various dimensions of psychophysically based intelligence. But he detected no unifying associations. Moreover, the psychophysical tests did not predict college grades. Therefore, the psychophysical approach to assessing intelligence soon faded almost into oblivion. It would reappear many years later in a somewhat different guise.

Binet, Terman, and Wechsler

An alternative to the psychophysical approach was developed by French psychologists Alfred Binet and his collaborator, Theodore Simon. They also attempted to assess intelligence, but their goal was more practical than purely scientific. Binet had been asked to devise a procedure for distinguishing normal learners from learners who are intellectually disabled (Binet & Simon, 1916). Binet and his collaborator set out to measure intelligence as a function of the ability to learn within an academic setting. In Binet's view, judgment is the key to intelligence; not psychophysical acuity, strength, or skill.

For Binet (Binet & Simon, 1916), intelligent thought (mental judgment) comprises three distinct elements: direction, adaptation, and criticism. *Direction* involves knowing what must be done and how to do it; *adaptation* refers to customizing a strategy for performing a task and then monitoring that strategy while implementing it; and *criticism* is the ability to critique your own thoughts and actions. The importance of direction and adaptation certainly fits with contemporary views of intelligence, and Binet's notion of criticism seems prescient, considering the current appreciation of metacognitive processes as a key aspect of intelligence.

Initially, when Binet and Simon developed their intelligence test, they were interested in some means of comparing the intelligence of a given child with that of other children of the same chronological age (CA). For their purposes, they sought to determine each child's *mental age*—the average level of intelligence for a person of a given age. Therefore, a mental age of 7 refers to the level of thinking reached by an average 7-year-old child. Mental ages worked just fine for comparing a given 7-year-old child with other 7-year-old children, but the use of mental ages made it difficult to compare relative intelligence in children of differing chronological ages.

William Stern suggested in 1912 that intelligence should be evaluated by using an *intelligence quotient* (IQ): a ratio of mental age (MA) divided by CA and multiplied by 100. Therefore, if Joan's mental age is 5 and her chronological age is 5, then her intelligence is average and her IQ is 100—$(MA = 5/CA = 5) \times 100 = 100$. When mental age exceeds chronological age, the ratio will lead to an IQ score above 100, and when chronological age exceeds mental age, the ratio will lead to an IQ score below 100. Intelligence scores that are expressed in terms of a ratio of mental age to chronological age are termed *ratio IQs*.

For various reasons, ratio IQs, too, proved inadequate. For example, increases in mental age slow down at about 16 years old. An 8-year-old child with a mental age of 12 years is pretty smart. However, is a 40-year-old adult with a mental age of 60 similarly intelligent, which the ratio IQ seems to suggest as it is the same for the 8-year-old child and the 40-year-old adult? What does a mental age of 60 mean? Today, psychologists rarely use IQs based on mental ages. Instead, researchers have turned to measurement comparisons on the basis of assumed normal distributions of test scores within large populations. Scores calculated on the basis of deviations from the middle score in a normal distribution of scores on a test of intelligence are termed *deviation IQs*. Many cognitive theorists believe that IQs provide only incomplete measurement of intelligence.

Lewis Terman, an American psychologist at Stanford University, built on Binet and Simon's work in Europe and constructed the earliest version of what has come to be called the Stanford–Binet Intelligence Scale (see Roid, 2003). For years, the Stanford–Binet test was the standard for intelligence tests, and it still is widely

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used today. The competitive Wechsler scales are even more widely used, however (Pfeiffer, 2015).

American psychologist David Wechsler, like Binet, had a conception of intelligence that went beyond what his own test measured. Wechsler clearly believed in the worth of attempting to measure intelligence, but he did not limit his conception of intelligence to test scores. Wechsler believed that intelligence is central in our everyday lives. Intelligence is not represented just by a test score or even by what we do in school. We use our intelligence not just in taking tests and in doing homework, we also use it in relating to people, in performing our jobs effectively, and in managing our lives in general.

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Additional Approaches to Theory and Research

A focus on the measurement of intelligence is only one of several approaches to theory and research on intelligence. At least two key issues need to be considered in the cognitive approach to studying intelligence—whether cognitive psychologists should focus on the measurement of intelligence or on the processes of intelligence, and what underlies intelligence (genetic inheritance, acquired attributes, or some kind of interaction between the two). Today, psychologists overwhelmingly accept the notion that intelligence derives from an interaction of genetic and environmental factors (Deary, Johnson, & Houlihan, 2009; Mandelman & Grigorenko, 2011).

Psychologists interested in the structure of intelligence have relied on factor analysis as the indispensable tool for research. *Factor analysis* is a statistical method for separating a construct (i.e., intelligence) into a number of hypothetical factors or abilities that the researchers believe to form the basis of individual differences in test performance (Willis, Dumont, & Kaufman, 2011). The specific factors derived, of course, still depend on the specific questions being asked and the tasks being evaluated.

A problem with factor analysis is that it is a self-contained system in the sense that what one gets out is always completely determined by the range of what one puts in. That is, if one puts in a narrow range of tests, the breath of the factors will be constrained by the narrow range of tests. This is relevant because, for the most part, the kinds of tests entered into factor analysis have changed little since the early 20th century. It therefore is not surprising that we keep seeming to confirm what we learned in the 20th century. If we don't broaden the range of tests, we will not broaden the conception of intelligence on the basis of these tests.

RELEVANT THEORY AND PRINCIPLES

Factor analysis is based on studies of correlation. The idea is that the more highly two tests are correlated, the more likely they are to measure the same thing. In research on intelligence, a factor analysis might involve the following steps: (a) give a large number of people several different tests of ability, (b) determine the correlations among those tests, and (c) statistically analyze those correlations to simplify them into a relatively small number of factors that summarize people's performance on the tests. The investigators in this area generally have agreed on and followed this procedure. Yet the resulting factorial structures of intelligence have differed among different theorists. Among the many competing factorial theories, the theories by Spearman, Thurstone, Guilford, Cattell, Vernon, Carroll, and Johnson and Bouchard are the most important.

Spearman: The "g" Factor

Charles Spearman, an English psychologist credited with inventing factor analysis (Spearman, 1927), used factor-analytic studies to conclude that intelligence could be understood in terms of two kinds of factors. A single general factor pervades performance on all tests of mental ability. A set of specific factors is involved in performance on only a single type of mental-ability test (e.g., arithmetic computations). In Spearman's view, the specific factors are of only casual interest because of the narrow applicability of these factors. The general factor, which Spearman labeled "g," provides the key to understanding intelligence. Spearman believed "g" to be the result of "mental energy." Many psychologists still believe Spearman's theory to be correct (see essays in Sternberg & Grigorenko, 2013).

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Thurstone: Primary Mental Abilities

In contrast to Spearman, Louis Thurstone, an American psychometrician, concluded that the core of intelligence resides not in one single factor but in seven such factors (Thurstone, 1938). He referred to these as *primary mental abilities*: verbal comprehension, verbal fluency, inductive reasoning, spatial visualization, number, memory, and perceptual speed. These components provide a direct means to measure intelligence as defined by Thurstone (1938).

Hierarchical Models

A more parsimonious way of handling the factors of the mind is through a hierarchical model of intelligence. One such model proposed that general intelligence comprises two major subfactors: fluid ability and crystallized ability. *Fluid ability* is speed and accuracy of abstract reasoning, especially for novel problems. Crystallized ability is accumulated knowledge and vocabulary (Cattell, 1971). Subsumed within these two major subfactors are other, more specific factors. A similar view is a general division between practical-mechanical and verbal-educational abilities (Vernon, 1971).

A more recent model is a hierarchy comprising three strata (Carroll, 1993). Stratum I includes many narrow, specific abilities (e.g., spelling ability, speed of reasoning). Stratum II includes various broad abilities (e.g., fluid intelligence, crystallized intelligence). And Stratum III is just a single general intelligence, much like Spearman's g. Of these strata, the most interesting is the middle stratum, which is neither too narrow nor too all encompassing.

In addition to fluid intelligence and crystallized intelligence, several other abilities are included in the middle stratum: learning and memory processes, visual perception, auditory perception, facile production of ideas (similar to verbal fluency), and speed (speed of response and speed of accurate response). Carroll's (1993) model is probably the most widely accepted of the psychometric models. Although the factor-analytic approach it exemplifies has tended to emphasize the structures of intelligence, the information-processing approach has tended to emphasize the operations of intelligence.

Johnson and Bouchard (2005) proposed a variation of hierarchical theory in which they suggested that abilities are properly divided not into fluid abilities and crystallized abilities, but rather into verbal abilities, perceptual abilities, and image rotation. Their argument is that spatial abilities such as the ability to rotate images of objects in the mind are relatively distinct from either fluid or crystallized intelligence.

What does it mean to be gifted, then, according to psychometric theories? It means that one is very high-scoring on some subset of the psychometric tests used by factor analysts to measure intelligence. What has never been agreed on is how the different factors should be combined. An IQ is an overall measure of those factors. So, identifying someone as gifted on the basis of IQ is essentially a statement that the abilities should be considered additively. An alternative model would be a threshold model; that is, labeling someone as "gifted" if he or she exceeds a high threshold on any one of the factors. In that case, a person might have a lower IQ but excel, say, in verbal, mathematical, or spatial abilities. Because, in the adult world, people who stand out usually stand out in something, there is something to be said for using some kind of threshold model, recognizing that people who excel in one thing may not necessarily be at the top in others. That is, despite a lower IQ, they may be worthy of being labeled as gifted because they are good at one particular skill or set of skills.

RESEARCH REVIEW

Information Processing and Intelligence

Information-processing theorists are interested in studying how people mentally manipulate what they learn and know about the world (Hunt, 2010; Mackintosh, 2011). The ways in which various information-processing investigators study intelligence differ primarily in terms of the complexity of the processes being studied (Lohman & Lakin, 2011). Researchers have considered the speed and the accuracy of information processing to be important factors in intelligence.

Process-Timing Theories

Process-timing theories emphasize speed of information in the brain. For example, *inspection time* is

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the amount of time it takes you to inspect items and make a decision about them. It is measured through an inspection-time experimental paradigm (Nettelbeck, 2011). For each of a number of trials, a computer monitor displays a fixation cue (a dot in the area where a target figure will appear) for 500 ms. There is then a pause of 360 ms. Following this period, the computer presents the target stimulus for a particular interval of time. Finally, it presents a visual mask (a stimulus that erases the trace in iconic memory).

The target stimulus typically comprises two vertical lines of unequal length (e.g., 25 mm and 35 mm). The two lines are aligned at the top by a horizontal crossbar. The shorter of the two lines may appear on either the right or the left side of the stimulus. The visual mask is a pair of lines that are thicker and longer than the two lines of the target stimulus. The task is to inspect the target stimulus and then indicate the side on which the shorter line appeared. A participant indicates the left-hand stimulus by pressing a left-hand button on a keypad connected to a computer that records the responses, and indicates the right-hand stimulus by pressing the right-hand button.

The key variable is the length of time for the presentation of the target stimulus, not the speed of responding by pressing the button. Nettelbeck (2011) defined inspection time operationally. It is the length of time for presentation of the target stimulus after which the participant still responds with at least 90% accuracy in indicating the side on which the shorter line appeared. He found that shorter inspection times correlate with higher scores on intelligence tests (e.g., various subscales of the Wechsler Adult Intelligence Scale) among differing populations of participants.

Choice Reaction Time

Some investigators have proposed that intelligence can be understood in terms of speed of neuronal conduction (e.g., Jensen, 1998; see Nettelbeck, 2011). In other words, the smart person is someone whose neural circuits conduct information rapidly. When Jensen (1998) proposed this notion, direct measures of neural-conduction velocity were not readily available. So, Jensen primarily studied a proposed proxy for measuring neural-processing speed. The proxy was *choice reaction time*—the time it takes to select one answer from among several possibilities.

Consider a typical choice-reaction-time paradigm: A participant is seated in front of a set of lights on a board. When one of the lights flashes, the participant extinguishes it by pressing as rapidly as possible a button beneath the correct light. The experimenter would then measure the participant's speed in performing this task.

Participants with higher IQs are faster than participants with lower IQs in their reaction time (Jensen, 1998). In this particular version of the task, *reaction time* is defined as the time when a light comes on to the time the finger leaves the home (central) button. In some studies, participants with higher IQs also showed a faster *movement time*, which is defined as the time between letting the finger leave the home button and hitting the button under the light. These findings may be due to increased central nerve-conduction velocity, although at present this proposal remains speculative (Jensen, 1998).

Lexical-Access Speed and Speed of Simultaneous Processing

Some investigations have focused on *lexical-access speed*—the speed with which we can retrieve information about words (e.g., letter names) stored in our long-term memories (Hunt, 1978). This speed can be measured with a letter-matching, reaction-time task first proposed by Posner and Mitchell in 1967 (see Hunt, 1978).

Participants are shown pairs of letters, such as "A A," "A a," or "A b." For each pair, they indicate whether the letters constitute a match in name (e.g., "A a" match in name but "A b" do not). Participants also are given a simple task: they are asked to indicate whether the letters match physically (e.g., "A A" match physically but "A a" do not). The variable of interest is the difference between participants' speed for the first set of tasks, involving name matching, and their speed for the second set, involving matching of physical characteristics. The difference in reaction time between the two kinds of tasks is said to provide a measure of speed of

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lexical access. This score is based on a *subtraction* of name-match minus physical-match reaction time. The subtraction controls for mere perceptual-processing time. Students with lower verbal ability take longer to gain access to lexical information than do students with higher verbal ability (Hunt, 1978).

Intelligence is also related to people's ability to divide their attention (Hunt & Lansman, 1982). For example, suppose that participants are asked to solve mathematical problems and simultaneously to listen for a tone and press a button as soon as they hear it. We can expect that people with higher intelligence would solve the math problems effectively and respond quickly to hearing the tone. According to Hunt and Lansman (1982), intelligent people are better able to timeshare between two tasks and to perform both effectively.

Process-timing theories attempt to account for differences in intelligence by appealing to differences in the speed of various forms of information processing. Inspection time, choice reaction time, and lexical access timing have been found to correlate with measures of intelligence. These findings suggest that, on average, higher intelligence may be related to the speed of various information-processing abilities. More intelligent people encode information more rapidly into working memory. They access information in long-term memory more rapidly. And they respond more rapidly. Why would more rapid encoding, retrieval, and responding be associated with higher intelligence test scores? Do rapid information processors learn more?

Working Memory

Working memory is a critical component of intelligence. Indeed, some investigators have argued that intelligence may be little more than working memory (Conway, Getz, Macnamara, & de Abreu, 2011; Kyllonen & Christal, 1990). In one study, participants read sets of passages and, after they had read the passages, tried to remember the last word of each passage (Daneman & Carpenter, 1983). Recall was highly correlated with verbal ability. In another study, participants performed a variety of working-memory tasks. In one task, for example, the participants saw a set of simple arithmetic problems, each of which was followed by a word or a digit (e.g., $(3 \times 5) - 6 = 7$ TABLE; see Hambrick, Kane, & Engle, 2005). The participants saw sets of two to six such problems and solved each one. After solving the problems in the set, they tried to recall the words that followed the problems. The number of words recalled was highly correlated with measured intelligence.

There are indications that a measure of working memory can provide a high level of prediction of scores on tests of general ability. Therefore, it appears that the ability to store and manipulate information in working memory may be an important aspect of intelligence. It is probably not all there is to intelligence, however.

Componential Theory and Complex Problem Solving

Cognitive approaches for studying information processing can be applied to more complex tasks, such as analogies, series problems (e.g., completing a numerical or figural series), and syllogisms (Sternberg, 1977, 1985a). The idea is to take the kinds of tasks used on conventional intelligence tests and to isolate components of intelligence. *Components* are the mental processes used in performing these tasks, such as translating a sensory input into a mental representation, transforming one conceptual representation into another, or translating a conceptual representation into a motor output. Many investigators have elaborated on and expanded this basic approach (see Duggan & Garcia-Barrera, 2015; Lohman & Lakin, 2011, for reviews).

Componential analysis breaks down people's reaction times and error rates on these tasks in terms of the processes that make up the tasks. This kind of analysis revealed that people solve analogies and similar tasks by using several component processes: (a) encoding the terms of the problem; (b) inferring relations among at least some of the terms; (c) mapping the inferred relations to other terms, which would be presumed to show similar relations, and (d) applying the previously inferred relations to the new situations.

There are significant correlations between speed in executing these processes and performance on other, traditional intelligence tests. However, a more intriguing discovery is that participants who score higher on traditional intelligence tests take longer to encode the terms of the problem than do less intelligent participants. But they make up for the extra time by taking less time to perform the remaining components of the task. In general, more intelligent participants take longer during *global planning*—encoding the problem and formulating a general strategy for attacking the problem (or set of problems). But they take less time for *local planning*—forming and implementing strategies for the details of the task (Sternberg, 1985a).

The advantage of spending more time on global planning is the increased likelihood that the overall strategy will be correct. Therefore, when taking more time is advantageous, more intelligent people take longer to do something than less intelligent people (e.g., more time researching and planning a term paper but less time writing it). More intelligent people seem to spend more time planning for and encoding the problems they face, but they spend less time engaging in the other components of task performance. This may relate to the previously mentioned metacognitive attribute included in many notions of intelligence.

Researchers have also studied information processing of people engaged in complex problem-solving situations (e.g., playing chess, performing logical derivations; see essays in Davidson & Sternberg, 2003). For example, a simple, brief task might require the participants first to view an arithmetic or geometric series. Then they must figure out the rule underlying the progression. And finally they must guess what numeral or geometric figure might come next. Can performance on these or other tasks be analyzed at a biological level?

The information-processing view allows a considerable degree of flexibility in how a person will be determined to be gifted. It could be because the person represents information well, is gifted in picking strategies for solving problems, is quick in solving the problems, knows how best to allocate time in solving the problems, or so on. An advantage of the information-processing approach is precisely that it allows for so many different ways for a person to show how he or she excels. A disadvantage is that, in practical terms, schools probably do not want to invest the time and expense in viewing giftedness in such a complex way (i.e., in terms of mental representations, strategies, processing speeds, etc.). The result is that even information-processing theories, when reflected in standardized tests, tend to be greatly simplified so there is no clear way for users of test results to know precisely what aspects of information processing are bases of giftedness in a particular individual. The test might have a score for a set of skills such as working memory, but it probably will not have a score for things like mental representation and strategy formation or selection.

Biological Bases of Intelligence

The human brain is clearly the organ that serves as a biological basis for human intelligence (Haier, 2011). Early studies examined the brain to find biological indices of intelligence and other aspects of mental processes. They were a resounding failure, despite great efforts. As tools for studying the brain have become more sophisticated, however, we are beginning to see the possibility of finding physiological indicators of intelligence. The biological studies we now have are largely correlational. They show statistical associations between biological and psychometric or other measures of intelligence. They do not establish causal relations.

One line of research looks at the relationship of brain volume to intelligence (see Haier, 2011). The evidence suggests that, for humans, there is a modest but significant statistical relationship between brain size and intelligence (Haier, 2011). However, it is difficult to know what to make of this relationship. Greater brain size may cause greater intelligence, greater intelligence may cause greater brain size, or both may be dependent on some third factor. Moreover, it is probably as important how efficiently the brain is used than what is its size. For example, on average, men have larger brains than women. But women, on average, have better connections through the corpus callosum of the two hemispheres of the brain. So, it is not clear which sex would be, on average, at an advantage. It is important to note that the relationship between brain size and intelligence does not hold across species (Hofman, 2015). Rather, what holds seems to be a relationship between intelligence and brain size, relative to the rough general size of the organism.

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Neural efficiency may be related to intelligence (Neubauer & Fink, 2009). Such an approach is based on studies of how the brain metabolizes glucose (a simple sugar required for brain activity) during mental activities. Higher intelligence correlates with reduced levels of glucose metabolism during problem-solving tasks (Haier & Jung, 2007). That is, smarter brains consume less sugar and hence expend less effort than do less smart brains doing the same task. Furthermore, cerebral efficiency increases as a result of learning on a relatively complex task involving visuospatial manipulations (e.g., the computer game Tetris; Haier & Jung, 2007). As a result of practice, more intelligent participants not only show lower cerebral glucose metabolism overall but also show more specifically localized metabolism of glucose. In most areas of their brains, more intelligent participants show less glucose metabolism. But in selected areas of their brains, believed to be important to the task at hand, they show higher levels of glucose metabolism. Therefore, more intelligent participants may have learned how to use their brains more efficiently. They carefully focus their thought processes on a given task.

Some neuropsychological research suggests that performance on intelligence tests may fail to indicate a crucial aspect of intelligence. This is the ability to set goals, to plan how to meet them, and to execute those plans. Standardized IQ tests require responses to questions within a highly structured situation, but they do not require much in the way of goal setting or planning. They require participants to use what could be classified as crystallized intelligence. Damage to the posterior regions of the brain seems to have negative effects on measures of crystallized intelligence (Gray & Thompson, 2004), and these patients tend to perform poorly on standardized IQ tests. However, patients with frontal lobe damage perform well on these types of tests; but impairments in fluid intelligence are observed (Gray & Thompson, 2004). This result should come as no surprise, given that the frontal lobes are involved in reasoning, decision making, and problem solving. Other research highlights the importance of the parietal regions for performance on general and fluid intelligence tasks (Colom et al., 2009). Intelligence involves the ability to learn from experience and to adapt to the surrounding environment (Greenwood, 2015). Therefore, the ability to set goals and to design and implement plans cannot be ignored. An essential aspect of goal setting and planning is the ability to attend appropriately to relevant stimuli and the ability to ignore or discount irrelevant stimuli.

The discovered importance of the frontal and parietal regions in intelligence tasks has led to the development of an integrated theory of intelligence that highlights the importance of these areas. This theory, called the parietal-frontal integration theory (P-FIT), stresses the importance of interconnected brain regions in determining differences in intelligence: the Brodmann areas, the prefrontal cortex, the inferior and superior parietal lobule, the anterior cingulate, and portions of the temporal and occipital lobes (Jung & Haier, 2007). P-FIT theory describes patterns of brain activity in people with different levels of intelligence; it cannot, however, explain what makes a person intelligent or what is intelligence.

We cannot realistically study a brain or its contents and processes in isolation without also considering the entire human being. We must consider the interactions of that human being with the entire environmental context within which the person acts intelligently. Hence, many researchers and theorists urge us to take a more contextual view of intelligence. Some alternative views of intelligence attempt to broaden the definition of intelligence to be more inclusive of people's varied abilities.

Biological ideas provide an additional perspective on how children can be identified as gifted. A problem is that none of the biological measurements is at a point at which it could be used to provide reliable and valid identifications. For some time, such identification of the gifted has seemed to be "just around the corner," but it remains so now just as it was in the latter part of the 20th century. It is not clear when we will "turn the corner" in terms of having measurements that are practical to use in school settings.

PRACTICE AND POLICY ISSUES: CULTURAL CONTEXT AND INTELLIGENCE

According to *contextualism*, intelligence must be understood in a real-world and cultural context.

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The context of intelligence may be viewed at any level of analysis. It may be focused narrowly, as on the home and family environment, or it may be extended broadly, to entire cultures. For example, even cross-community differences have been correlated with differences in performance on intelligence tests, including those of rural versus urban communities, low versus high proportions of teenagers to adults within communities, and low versus high socioeconomic status of communities (see Barnett, Rindermann, Williams, & Ceci, 2011). Contextualists have been intrigued particularly by the effects of cultural context on intelligence.

Contextualists consider intelligence to be inextricably linked to culture (Ang, Van Dyne, & Tan, 2011). They view intelligence as something that a culture creates to define the nature of adaptive performance in that culture. It further accounts for why some people perform better than others on the tasks that a culture values (Sternberg, 2004). Theorists who endorse this model study just how intelligence relates to the external world in which the model is being applied and evaluated. In general, definitions and theories of intelligence will more effectively encompass cultural diversity by broadening in scope. Before exploring some of the contextual theories of intelligence, we will look at what prompted psychologists to believe that culture might play a role in how we define and assess intelligence.

There have been many definitions of culture (e.g., Ang, Van Dyne, & Tan, 2011; Saklofske et al., 2015). *Culture* is defined here as a set of attitudes, values, beliefs and behaviors shared by a group of people that is transmitted from one generation to the next. One reason to study culture and intelligence is that they are so inextricably interlinked. Indeed, culture is what, in large part, separates human intelligence from animal intelligence (see also Mandalaywala, Fleener, & Maestripieri, 2015; Zentall, 2011, 2015). Humans have evolved as they have in part because of their cultural adaptations, which in turn develop from their ability, even in infancy, to understand others as intentional agents.

Many research programs demonstrate the potential hazards of single-culture research. For example, Nisbett (2003) has found that some cultures, especially Asian cultures, tend to be more dialectical in their thinking, whereas European and North American cultures tend to be more linear. Similarly, people from Asian cultures tend to take a different viewpoint than people from European and North American cultures when approaching a new object. In general, people from European and North American cultures tend to process objects independently of the context, whereas people from many Asian cultures process objects in conjunction with the surrounding context (Nisbett, 2003). In fact, some evidence suggests that culture influences many cognitive processes, including intelligence (Sternberg, 2004). As a result, individuals in different cultures may construct concepts in quite different ways, rendering results of concept-formation or identification studies in a single culture suspect (Medin & Atran, 1999). Groups may think differently about what appears superficially to be the same phenomenon—whether a concept or the taking of a test. What appears to be differences in general intelligence may in fact be differences in cultural properties (Helms-Lorenz, Van de Vijver, & Poortinga, 2003). Helms-Lorenz and colleagues (2003) argued that measured differences in intellectual performance may result from differences in cultural complexity; but complexity of a culture is extremely hard to define, and what appears to be simple or complex from the point of view of one culture may appear different from the point of view of another.

In the Puluwat culture of Micronesia, sailors navigate incredibly long distances. They use none of the navigational aids that sailors from technologically advanced countries would need to get from one place to another (Gladwin, 1970). Suppose Puluwat sailors were to devise intelligence tests for Americans—they might not seem very intelligent. Similarly, the highly skilled Puluwat sailors might not do well on American-crafted tests of intelligence. These and other observations have prompted quite a few theoreticians to recognize the importance of considering cultural context when intelligence is assessed.

Another study provides an example a little closer to home regarding the effects of cultural differences on intelligence tests. Sarason and Doris (1979) tracked the IQs of Italian American immigrant.

Less than a century ago, first-generation Italian American children showed a median IQ of 87 (low average; range 76–100). Their IQs were relatively low even when nonverbal measures were used and when so-called "mainstream American" attitudes were considered.

For example, a leading researcher of the day, Henry Goddard (1917), pronounced that 79% of Italian immigrants were "feebleminded." He also asserted that about 80% of Jewish, Hungarian, and Russian immigrants were similarly unendowed. Goddard also asserted that moral decadence was associated with this deficit in intelligence. He recommended that the intelligence tests he used be administered to all immigrants and that all those he deemed substandard selectively be excluded from entering the United States. But subsequent generations of Italian American students who take IQ tests today show slightly above-average IQs (Ceci, 1996). Other immigrant groups that Goddard had denigrated have shown similar "amazing" increases. Even the most fervent hereditarians would be unlikely to attribute such remarkable gains in so few generations to heredity. Cultural assimilation, including integrated education, seems a much more plausible explanation.

This argument may make it clear why it is so difficult to come up with a test that everyone would consider "culturally fair"—equally appropriate and fair for members of all cultures. If members of different cultures have different ideas of what it means to be intelligent, then the very behaviors that may be considered intelligent in one culture may be considered unintelligent in another. Take, for example, the concept of mental quickness. In mainstream U.S. culture, quickness usually is associated with intelligence. To say someone is "quick" is to say that the person is intelligent. Indeed, most group tests of intelligence are strictly timed. Even on individual tests of intelligence, the test-giver times some responses of the test-taker. Many information-processing theorists and even psychophysiological theorists focus on the study of intelligence as a function of mental speed.

In many cultures of the world, however, quickness is not at a premium. In these cultures, people may believe that more intelligent people do not rush into things. Even in our own culture, no one will view you as brilliant if you rush things that should not be rushed. It generally is not smart to decide on a marital partner, a job, or a place to live in the 20 to 30 seconds normally given to solve an intelligence-test problem. Therefore, there exists no perfectly culture-fair tests of intelligence. How then should we consider context when assessing and understanding intelligence?

It may be possible to achieve culture-relevant tests, if not culture-fair ones. Culture-relevant tests measure skills and knowledge that relate to the cultural experiences of the test-takers. Baltes, Dittmann-Kohli, and Dixon (1984), for example, have designed tests measuring skill in dealing with the pragmatic aspects of everyday life. Designing culture-relevant tests requires creativity and effort, but it is probably not impossible. For example, one study investigated memory abilities in Western culture versus the Moroccan culture (Wagner, 1978). It found that the level of recall depended on the content that was being remembered. Culture-relevant content was remembered more effectively than nonrelevant content. For example, when compared with North American or European participants, Moroccan rug merchants were better able to recall complex visual patterns on black-and-white photos of Oriental rugs. Sometimes tests just are not designed to minimize the effects of cultural differences. In such cases, the key to culture-specific differences in memory may be the knowledge and use of metamemory strategies, rather than actual structural differences in memory (e.g., memory span and rates of forgetting; Wagner, 1978).

Research has shown that rural Kenyan school children have substantial knowledge about natural herbal medicines they believe fight illnesses. European and North American children would not be able to identify any of these medicines (see Sternberg, 2004). In short, making a test culturally relevant appears to involve much more than just removing specific linguistic barriers to understanding.

Similar context effects appear in children's and adults' performance on a variety of tasks. Three kinds of context affect performance (Ceci & Roazzi, 1994): social context (e.g., a task is considered

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masculine or feminine), mental context (e.g., whether a visuospatial task involves buying a home or burgling it), and physical context (e.g., whether a task is presented at the beach or in a laboratory). For example, 14-year-old boys performed poorly on a task when it was presented as a cupcake-baking task, but they performed well when it was framed as a battery-charging task (Ceci & Bronfenbrenner, 1985). Brazilian maids had no difficulty with proportional reasoning when hypothetically purchasing food, but they had great difficulty with it when hypothetically purchasing medicinal herbs (Nuñes, Schliemann, & Carraher, 1993). Brazilian children whose poverty had forced them to become street vendors showed no difficulty in performing complex arithmetic computations when selling things, but they had great difficulty performing similar calculations in a classroom (Nuñes, Schliemann, & Carraher, 1993). Test performance may be affected by the context in which the test terms are presented. The extent to which the context of performance resembles the context of learning of an intelligent action may partially determine the extent to which the behavior shows transfer from the first situation to the second.

In the following studies, the investigators looked at the interaction of cognition and context. Several investigators have proposed theories that seek explicitly to examine this interaction within an integrated model of many aspects of intelligence. Such theories view intelligence as a complex system.

Multiple Intelligences: Gardner

Howard Gardner (1983; Davis, Christodoulou, Seider, & Gardner, 2011) has proposed a theory of multiple intelligences, in 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 8 distinct intelligences that are relatively independent of each other: linguistic, logical/mathematical, spatial, bodily-kinesthetic, musical, naturalist, interpersonal, and intrapersonal. Each is a separate system of functioning, although these systems can interact to produce what we see as intelligent performance.

In some respects, Gardner's (1983; Davis et al., 2011) 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 8 intelligences. Gardner used converging operations. In particular, the theory uses 8 "signs" as criteria for detecting the existence of a discrete kind of intelligence (Gardner, 1983): potential isolation by brain damage, the existence of exceptional individuals (e.g., musical or mathematical prodigies), an identifiable core operation or set of operations (e.g., detection of relationships among musical tones), a distinctive developmental history leading from novice to master, distinctive evolutionary history, supportive evidence from cognitive-experimental research, supportive evidence from psychometric tests indicating discrete intelligences (e.g., differing performance on tests of visuospatial abilities versus on tests of linguistic abilities), and 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 (1983; Davis et al., 2011) 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 (1983; Davis et al., 2011) 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. Therefore, 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.

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Consider the phenomenon of preserved specific cognitive functioning in autistic savants, who 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 Triarchic Theory of Successful Intelligence: Sternberg

Whereas Gardner emphasizes the separateness of the various aspects of intelligence, Sternberg tended to emphasize the extent to which they work together in his triarchic theory of successful intelligence (Sternberg, 1985a, 1997, 2011). According to this theory, intelligence comprises three aspects: dealing with the relation of intelligence (a) to the internal world of the person, (b) to experience, and (c) to the external world.

How intelligence relates to the internal world. The internal part of the theory emphasizes the processing of information. Information processing can be viewed in terms of three different kinds of components: (a) metacomponents—higher-order executive processes (i.e., metacognition) used to plan, monitor, and evaluate problem solving, (b) performance components—lower-order processes used for implementing the commands of the metacomponents, and (c) knowledge-acquisition components—the processes used for learning how to solve the problems in the first place. These components are highly interdependent.

How intelligence relates to experience. The theory also considers how prior experience may interact with all three kinds of information-processing components. Each of us faces tasks and situations with which we have varying levels of experience. They range from a completely novel task, with which we have no previous experience, to a completely familiar task, with which we have extensive experience. As a task becomes increasingly familiar, many aspects of the task may become automatic. They require little conscious effort for determining what step to take next and how to implement that next step. A novel task makes demands on intelligence different from those of a task for which automatic procedures have been developed.

How intelligence relates to the external world. The triarchic theory also proposes that the various components of intelligence are applied to experience to serve three functions in real-world contexts: adapting to existing environments, shaping existing environments to create new environments, and selecting new environments. A person uses adaptation when he or she learns the ropes in a new environment and tries to figure out how to succeed in it.

According to the triarchic theory, people may apply their intelligence to many different kinds of problems. Some people may be more intelligent in the face of abstract, academic problems, whereas others may be more intelligent in the face of concrete, practical problems. An intelligent person does not necessarily excel in all aspects of intelligence. Rather, intelligent people know their strengths and weaknesses. They find ways in which to capitalize on their strengths and either to compensate for or to correct their weaknesses.

Sternberg and colleagues (1999) performed a comprehensive study testing the validity of the triarchic theory and its usefulness in improving performance. They predicted that matching students' instruction and assessment to their abilities would lead to improved performance. Students were selected for one of five ability patterns: high only in analytical ability, high only in creative ability, high only in practical ability, high in all abilities, or not high in any abilities. Then students were assigned at random to one of four instructional groups. These groups emphasized either memory-based, analytical, creative, or practical learning, and then the memory-based, analytical, creative, and practical achievement of all students was assessed. Sternberg and colleagues found that students who were placed in an instructional condition that matched their strength in terms of pattern of ability outperformed students who were mismatched. A high-analytical student placed in an instructional condition that emphasized analytical thinking outperformed a high-analytical student placed in an instructional condition that emphasized practical thinking.

Teaching students to use all of their analytic, creative, and practical abilities has resulted in improved school achievement for some students, whatever

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their ability pattern (see Sternberg, Jarvin, & Grigorenko, 2011), but this has not happened for all students (Sternberg et al., 2014).

One attempt to broaden the assessment can be seen through the Rainbow Project and related studies (Sternberg, 2010). In the Rainbow Project, students completed the SAT and additional assessments. These additional assessments included measures of creative, practical, and analytical abilities. The addition of these supplemental assessments resulted in superior prediction of college grade point average (GPA) as compared with scores on the SAT and high school GPA. In fact, the new tests doubled the prediction of first-year college GPA obtained just by the SAT. Moreover, the new assessments substantially reduced differences in scores among members of diverse ethnic groups.

FUTURE CONSIDERATIONS AND DIRECTIONS

Theories of intelligence are moving in many directions. I believe the main theoretical questions in need of resolution are (a) what exactly is intelligence, (b) how intelligence can be best measured, (c) what are the respective roles of the brain and the cultural context, and (d) whether intelligence itself is a dated concept that needs to be replaced by something else.

SUMMARY AND CONCLUSIONS

Theories of intelligence come in many different forms. The main forms are psychometric theories, information-processing (cognitive theories), biological theories, contextual theories, and integrative theories. These types of theories are not mutually exclusive. Rather, each type builds on other types to yield a more comprehensive picture of the nature of intelligence.

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