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Introduction

> Theory about intelligence is more fully developed and more mathematically sophisticated than for almost any other psychological construct. More is known about the underlying cognitive, genetic, and brain processes for intelligence than for any other complex psychological construct.
>
> (Detterman, 2014, p. 148)

> Intelligence testing may be psychology's greatest single achievement . . .
>
> (Gottfredson, 2009, p. 11)

As these quotes show, the scientific study of intelligence is probably the greatest success story in psychology – possibly in all the social sciences. For over 100 years scientists – first psychologists, but later education researchers, sociologists, geneticists, and more – have studied human intelligence. Now, two decades into the twenty-first century, the results are impressive. The evidence of the importance of intelligence has accumulated to such an extent that informed scientists now cannot deny that intelligence is one of the most important psychological traits in humans (Detterman, 2014; Gottfredson, 1997a).

But many people – even psychologists – are not aware of this fact. Unfortunately, inaccurate information and mistruths abound. In media reports the public is told that, "IQ tests are meaningless and too simplistic" (McDermott, 2012). Textbook authors state that, "the question [exists] of whether our tests truly measure intelligence, or whether they merely measure what is *called* intelligence in our culture" (Gleitman, Gross, & Reisberg, 2011, p. 440). Colleges do not teach about the concept (Burton & Warne, 2020), and the scholarly literature contains claims that the concept of intelligence and/or intelligence testing has been debunked (e.g., K. Richardson, 2002).

I wrote this book as an attempt to correct the mismatch between what experts believe about intelligence and what the public often hears – a mismatch that scholars have commented on many times (e.g., Detterman, 2014;

Gottfredson, 1994; Lubinski, 2004; Rindermann, Becker, & Coyle, 2020; Snyderman & Rothman, 1987, 1988; Wainer & Robinson, 2009). Having studied the topic for over 10 years, it is apparent to me that intelligence is underappreciated and neglected among both psychologists and laypeople. Misunderstandings and inaccuracies – sometimes propagated with the best of intentions – have inhibited scientific and social progress. These erroneous beliefs are so common that when I compiled a list, I found that there were enough to fill a book. This is that book.

WHAT IS INTELLIGENCE?

While there is not unanimous agreement about a definition of intelligence (there never is for any concept in the social sciences), the definition that seems to have a great deal of consensus states:

> Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings – "catching on," "making sense" of things, or "figuring out" what to do. (Gottfredson, 1997a, p. 13)

Although it may not seem like a bold statement at first glance, Gottfredson's (1997a) definition is audacious in its claim that the same mental ability that causes people to think abstractly also causes people to learn quickly, comprehend the environment, and plan. In the early days of psychology, many people thought that these different tasks would require different mental abilities (e.g., Joseph Peterson, 1926/1969; Terman, 1932; Thurstone, 1936). However, in the twenty-first century the consensus is that there is one general ability – often called intelligence – that helps people perform all the mental tasks in the definition.

Intelligence Test Items. The best way to measure intelligence is through a professionally designed test that requires examinees to reason, solve problems, think abstractly, or demonstrate their knowledge. Questions on intelligence tests, often called *items*, can take many forms. Some will look familiar, perhaps because you remember similar questions on academic tests or because you have taken an intelligence test. Others may appear very strange. One of the oldest types of items on an intelligence test is vocabulary items, which require an examinee to define words in their native language. Easier items tend to ask examinees to define basic words (e.g., "moon," "hand," or "mother"), while more difficult items ask about abstract or unusual word (e.g., "conflate," "perturb," or "esoteric").

There are other types of *vocabulary items* that do not ask the examinee to generate a definition for a word. For some tests (especially written tests), the examinee must know the definition of a word in order to answer a question about vocabulary correctly. For example, in a series of four words, the examinee may need to identify which does not belong with the others (e.g.,

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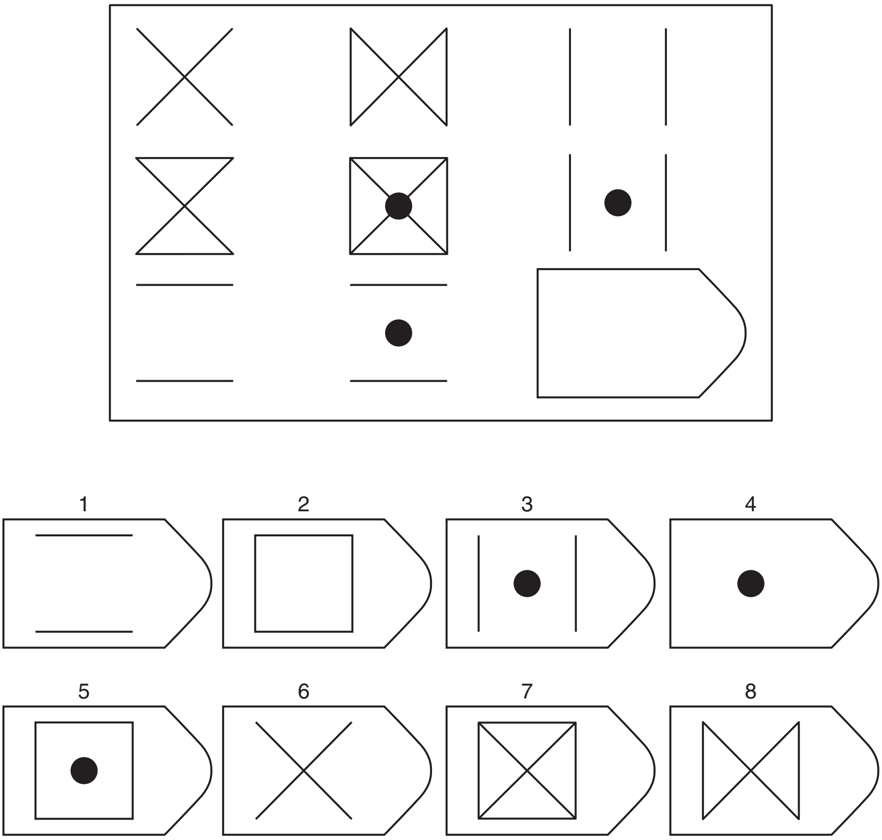

FIGURE I.1 Example of a matrix item. The series of geometric shapes at the top of the image forms a pattern which is missing the bottom right portion. One of the eight options below correctly completes the pattern. The correct response is 4.
Source: Fox & Mitchum, 2013, p. 982.

"photograph, painting, calculator, sculpture"). Verbal analogies (such as "old is to young as white is to ________") are items asking about the relationship among words, and sentence completion questions often measure vocabulary knowledge and word usage.

Another common type of intelligence test item is called a *matrix item*, an example of which is shown in Figure I.1. The large box in the upper portion of the image contains a series of geometric shapes that form a pattern. The bottom right portion of the pattern (indicated by the outline that looks like a price tag) is missing. The examinee then must decide which of the eight options below completes the pattern.

A common type of intelligence test item is the *digit span* procedure. In this technique, the examiner reads a series of one-digit numbers to the examinee, who

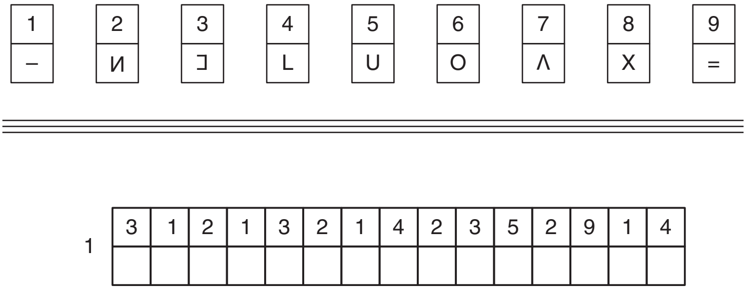

FIGURE I.2 Example of a coding item. The upper portion of the image is a key indicating which symbols should be matched with each number. In the lower portion, the examinee is supposed to draw below each number the symbol that it corresponds to.
Source: Yerkes, 1921, p. 254.

then must repeat the digits in the same order back to the examiner. Other forms of digit span include backward digit span (requiring the examinee to repeat the sequence in reverse order), picture span (which uses pictures that must be reproduced in the correct order, instead of a verbal presentation of numbers), letter–number sequencing (where a combination of letters and numbers is in the sequence, instead of just numbers), and block span (where the examiner taps a sequence of blocks, which the examinee must also touch in the same order).

More straightforward are *information items*, which ask an examinee to recall information that is important in their native culture. For example, one now-obsolete information item asked American children, "Who wrote *Romeo and Juliet*?" Many information items appear similar to trivia questions and are seemingly random in their content.

Another type of intelligence test question is *coding items*; an example from a long-obsolete test (Yerkes, 1921, p. 254) is shown in Figure I.2. The top portion of the figure is a key that shows which symbols correspond to each number. The examinee must draw the correct symbol below each number in the lower portion of the image. Often coding items have short time limits that make the test more difficult.

Other types include *arithmetic* items, *cancellation* (where a person is given a page full of random letters or numbers and told to cross out all of the same symbols – like *a*'s or *3*'s – on the paper), *block design* (which requires an examinee to assemble a set of colored blocks to produce a design that they are shown), and *picture completion* (a type of item where examinees must explain what essential component of an object is missing from a picture they are shown). Another item type is the *sequence completion* items, which give a series of symbols – usually numbers – that form a pattern that the examinee must complete (for example, "5, 2, 9, 6, 13, _____").

There are also picture items that have a visual stimulus. For example, a *picture absurdity* item might show an image of a hose spraying water while disconnected from a water source. The examinee would then have to explain what is absurd about the image. Pattern completion items and memory sequences can also be administered with pictures. Many items that measure *spatial reasoning*, which is the ability to reason and think about objects in two or three dimensions, also have a pictorial format, such as the ones shown in Figure I.3.

These are just some of the most common types of intelligence test questions. Jensen (1980a, pp. 148–166) describes many more – all with examples. It is important to recognize, though, that no intelligence test has every type of item on it. In fact, some have only one.

Other Characteristics of Intelligence Tests. Beyond item format, intelligence tests vary in many other ways. Some are administered to one examinee at a time by a professional with a master's or doctorate degree, while others require no special training for the examiner and can be administered to groups. Some require examinees to respond verbally, while others accept written responses or non-verbal responses (e.g., pointing, pressing a button, or clicking a mouse). Some intelligence test questions require the examinee to perform a task – like assemble a puzzle or draw a picture – while others merely require answering questions. Some use culturally relevant knowledge like information about the history of the examinee's native country, while the creators of other tests try to minimize cultural content by using geometric figures or culturally universal concepts (e.g., up and down, the sun and moon) in the test materials.

Despite the diversity in test administration, format, and content, all these tests measure intelligence because *it is not the surface content of a test that determines whether it measures intelligence. Rather, it is what the test items require examinees to do that determines whether a test measures intelligence*. As long as a test requires some sort of mental effort, judgment, reasoning, or decision making, it measures intelligence (Cucina & Howardson, 2017; Jensen, 1980a; Spearman, 1927). As a result, many tests function as intelligence tests, even if the test creators do not label them as "intelligence tests." These include college admissions tests (Frey & Detterman, 2004; Koenig, Frey, & Detterman, 2008), literacy tests (Gottfredson, 1997b, 2004), primary and secondary school academic achievement tests (W. M. Williams & Ceci, 1997), many job application tests (P. L. Roth, Bevier, Bobko, Switzer, & Tyler, 2001), and even everyday life tasks (Gottfredson, 1997b). Chapter 7 discusses this point further.

This is not to say that all of these tests are equally good at measuring intelligence. They're not. Backward digit span, for example, is a better measure of intelligence than digit span, but matrix items are better than both. In general, test items that are more complex are better measures of intelligence than basic tasks. But it is true that any task that requires cognitive work from a person will measure intelligence – at least partially.

Intelligence Test Scores. Often, the results of a professionally developed intelligence test produce an overall score of the person's performance on the test, called an *IQ score*. In the early days of intelligence testing, "IQ" was an abbreviation for "intelligence quotient," and the score was calculated using the

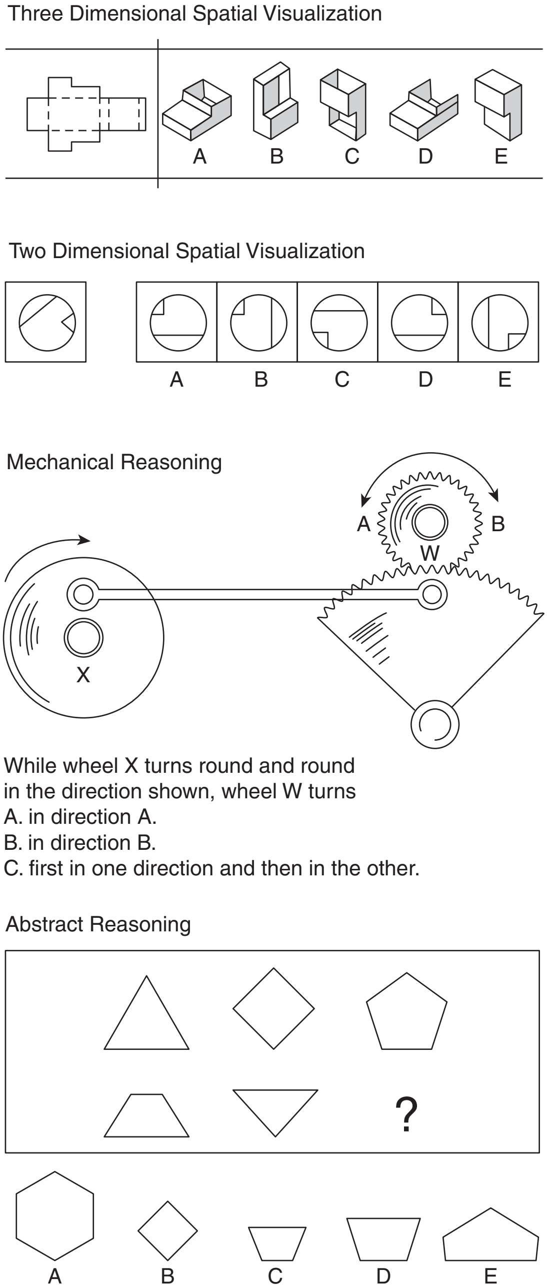

FIGURE I.3 Examples of items that measure spatial reasoning in two or three dimensions.
Source: Wai, Lubinski, & Benbow, 2009, p. 822.

following formula, introduced (according to Fancher, 1985) by German psychologist William Stern:

$$\frac{\textit{mental age}}{\textit{chronological age}} \times 100 = \text{IQ}$$

The fraction is the "quotient" part of the equation and is calculated by dividing the mental age by the chronological age. The examinee's "mental age" was found by identifying the age group that – on average – performed as well as the examinee. The "chronological age" was the examinee's actual age. For example, if a 5-year-old obtained a score that was typical for a 6-year-old, then her "mental age" would be 6, and her chronological age would be 5. Therefore, her IQ score would be calculated as:

$$\frac{6}{5} \times 100 = 120$$

Multiplying by 100 eliminates the decimal and sets 100 as the standard for average performance on an intelligence test in all age groups. Under this system, IQ scores greater than 100 indicate that the examinee scored above average for their age, while scores less than 100 indicate that the examinee performed more poorly than average for their age group.

This method of calculating IQ scores is now obsolete. Even when it was first developed and popularized during the 1910s, psychologists realized it had problems. First, scores were not comparable across age groups. For example, if our smart examinee with an IQ score of 120 at age 5 is still one year advanced compared to her peers when she is 10, her IQ would drop to:

$$\frac{11}{10} \times 100 = 110$$

Therefore, the interpretation of an IQ score varied from age group to age group. Indeed, 100 was the only score that was comparable across ages. It indicated that the examinee was average compared to their peers, no matter what age those peers were. A related problem is that the variability of scores changes from age to age, with children at younger ages usually having more variable IQ scores than older groups, which created additional difficulties when comparing scores across age groups.

Another problem was that this method of calculating IQ scores is completely inadequate for adults. While in children it makes sense to measure intelligence in terms of development, for most adults, intellectual development does not match age. It does not make sense, for example, to be concerned that a 40-year-old is as smart as a 20-year-old (which the quotient IQ formula would indicate means that the 40-year-old has an IQ of 50) because there is no reason to believe that normal adults would keep getting smarter as they age, the way children do.

To remedy these problems, psychologists now use a different method of calculating scores from intelligence tests. Called the *deviation score method*,

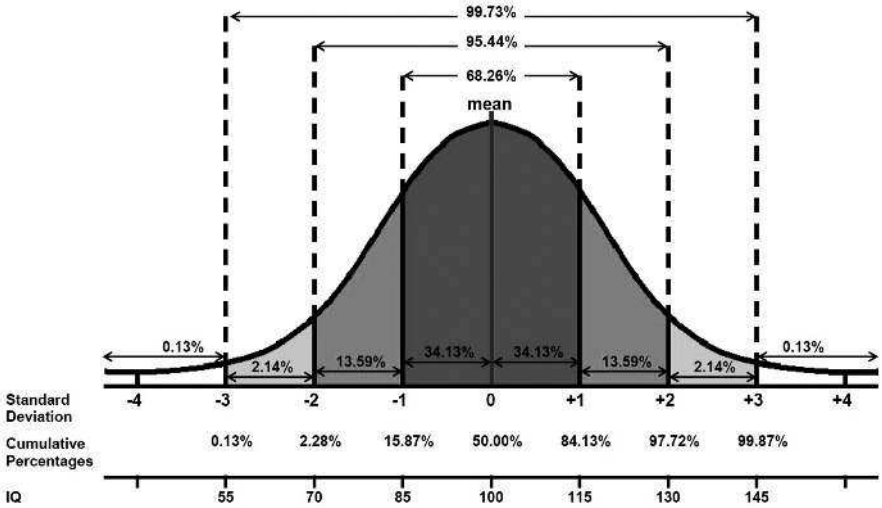

FIGURE I.4 A normal distribution of intelligence test scores. The average intelligence test score is 100 points, and the standard deviation is equal to 15 points. This means that 68.26% of individuals have an IQ score between 85 and 115, while 99.73% have an IQ score between 55 and 145.
Image created by Rosalma Arcelay, copyright Russell T. Warne, 2009.

it takes advantage of the fact that scores on intelligence tests often create a symmetrical bell-shaped distribution called a normal distribution (W. Johnson, Carothers, & Deary, 2008; Warne, Godwin, & Smith, 2013), which is pictured in Figure I.4. In this method, the examinee's test performance is compared to scores from a comparison group of the examinee's age peers (called a *norm group*). The degree of difference between the person's score and average is measured in a unit called the *standard deviation*. Figure I.4 shows that individuals who score at the average for a test are 0 standard deviations away from the mean score. Slightly more than two-thirds of people – 68.26% – score between -1 and +1 standard deviations from average, and almost everyone – 99.73% – scores between -3 and +3 standard deviations from the mean.

Once it is known how far above or below a person's score is compared to the average, this value is converted into an IQ score with the following equation:

$$\text{IQ} = z(15) + 100$$

In this equation, z is the number of standard deviations the person's score is away from average.

Although the deviation score method is more complicated, it is far better than the quotient method of calculating intelligence test scores. Scores are comparable across groups, have the same variability across age groups, and can be used for adults. Moreover, the deviation score method preserves all the advantages of the quotient method: average performance is still assigned a score of 100, and scores above 100 indicate better than average performance, while scores below 100 indicate poorer performance than average.

Modern professionally designed tests that are labeled as intelligence tests use the deviation score method to produce intelligence test scores that have an average of 100 points and a standard deviation of 15 points. However, academic tests, aptitude tests, employment tests, and other measures of intelligence often use other scales. These scores can be mathematically converted into the intelligence test score scale – and this is standard practice in intelligence research (e.g., Frey & Detterman, 2004; Koenig, Frey, & Detterman, 2008). In this book, I will always use this IQ metric, even if the original studies that I cite originally reported scores in another scale.

RELATIONSHIP WITH OTHER MENTAL ABILITIES

Intelligence is not the only mental ability, and everyone doing scholarly work in this field acknowledges that other mental abilities matter. For much of the twentieth century, there was active disagreement about how intelligence related to abilities like short-term memory, spatial reasoning, and verbal ability. Although there is still dissent within the scientific community, the most common model that psychologists use to understand the relationships among mental abilities is the *Cattell–Horn–Carroll (CHC) model* (Warne, 2016a), which is shown in Figure I.5.

The CHC model is organized in a hierarchy, with more general abilities at the top of the hierarchy, and narrower abilities at the bottom. The layers of abilities are labeled, from most specific to most general, as Stratum I (the bottom row), Stratum II (the middle row), and Stratum III (the top row). The only ability in Stratum III is general intelligence (labeled *g*), and it is the only ability that is theorized to be useful in performing all cognitive tasks. Beneath *g* is Stratum II, which consists of broad abilities that are not applicable in every situation. Examples include verbal ability, spatial reasoning, and processing speed. Finally, at the bottom of the CHC model is Stratum I, which consists of very specific abilities, including vocabulary knowledge, memory for digit span, arithmetic performance, reaction time, and many others.

The CHC model has a few important implications. First, it shows why so many tasks measure intelligence: only intelligence is applicable across every cognitive task, and every narrow task (shown in Stratum I) is subsumed beneath general intelligence. Second, it also shows how intelligence exerts its influence when people perform specific mental tasks: general intelligence is filtered through Stratum II abilities to be used to perform narrow, specific tasks.

Although the CHC model is the most popular theory of intelligence today (Hunt, 2011), there are other theories that have their adherents. One of these is

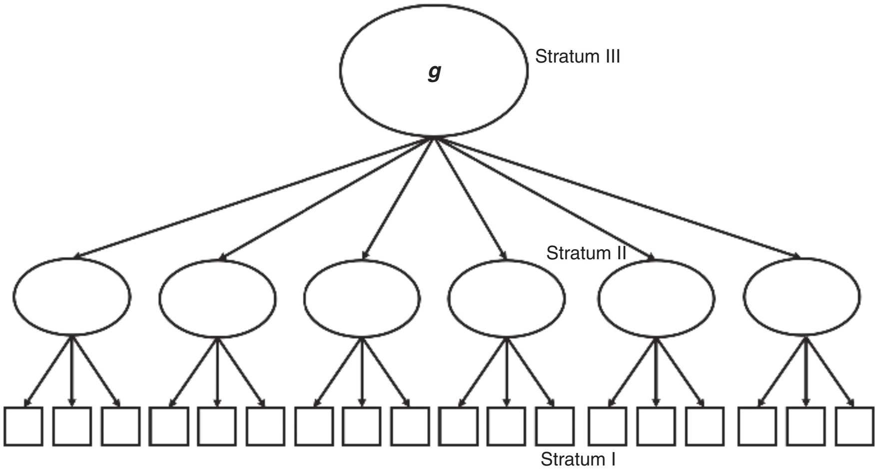

FIGURE I.5 Schematic of the Cattell–Horn–Carroll model of mental abilities. The bottom row of squares represents Stratum I, which consists of very narrow, specific abilities (e.g., vocabulary knowledge, memory for digit span, arithmetic performance). The middle row – called Stratum II – consists of ovals that represent broad abilities that are applicable in many situations (e.g., verbal ability, spatial reasoning, processing speed). At the top of the hierarchy is Stratum III, which consists only of general intelligence, abbreviated as *g*.

termed the *bifactor model* and is shown in Figure I.6. The bifactor model and the CHC both organize narrow abilities, broad abilities, and intelligence into Strata I, II, and III, respectively. The difference is that in the bifactor model, narrow abilities are subjected to the direct influences of a Stratum II ability *and* intelligence (Jensen, 1998). In the CHC model, *g* transmits its impact on a narrow Stratum I ability *through* a Stratum II ability, not directly.

For most purposes, whether one prefers the bifactor or CHC model does not matter. In most situations they produce very similar data and have similar practical implications. There are some minor exceptions (for example, in what to expect from efforts to raise IQ scores), but readers should assume – unless I state otherwise – that I am basing my discussion on the CHC model. Also, readers should be aware that I describe these models in terms of a mathematical procedure called factor analysis (described later in this introduction). However, the theories are not dependent upon any particular data analysis method. The three-strata structure emerged from other analysis procedures (Corno et al., 2002).

Finally, it should be noted that I will discuss two alternate theories about intelligence in this book: multiple intelligences theory (Chapter 5), and the triarchic theory of intelligence (Chapter 6). Although these theories have their