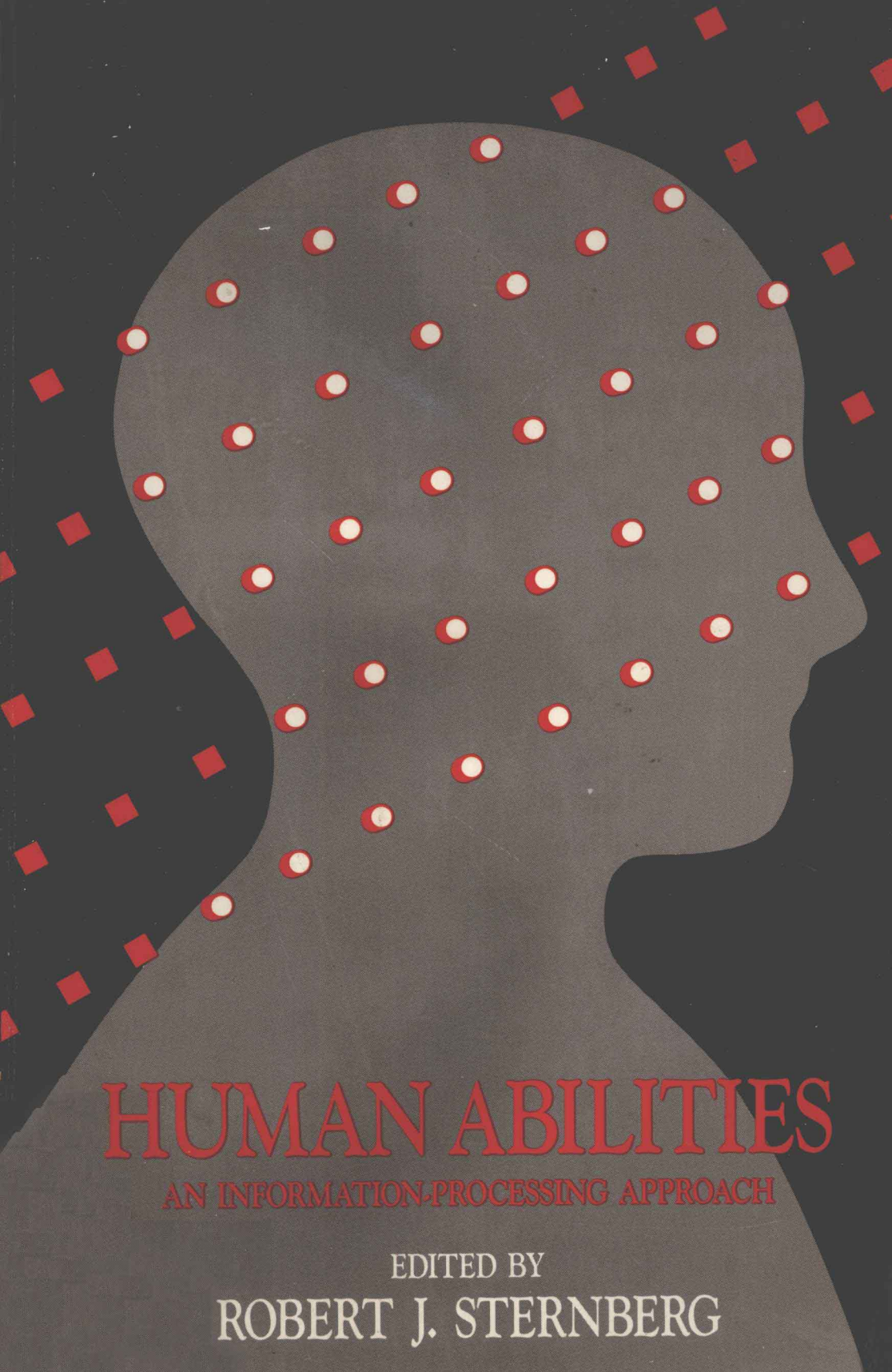

HUMAN ABILITIES

AN INFORMATION-PROCESSING APPROACH

EDITED BY

ROBERT J. STERNBERG

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This book is dedicated to Lee J. Cronbach, whose plea for the unification of the two disciplines of scientific psychology provided the impetus for much of the theory and research presented in this book.

PREFACE

The decision to prepare a book can come about through any of a number of distinct motivations. The decision to prepare this one came about through frustration—namely, my own frustration with the absence of an undergraduate or beginning graduate level text on human abilities that adequately represented the great strides that have been made during the past decade in our understanding of the information-processing bases of human abilities.

There is no lack of books on the subject of human abilities, broadly defined. But none of them have come even close to suiting me and my students as a text. After examining all the available books, I found that they fell into one (or more) of the following four classes:

1. Books on human abilities that adequately represent the psychometric, or differential, point of view, but that give either little or no coverage to the information-processing approach that dominates current attempts to understand the nature of abilities.
2. Books on human abilities that represent the information-processing approach, but that are at a level that assumes at least advanced graduate-level competence for a reasonable level of understanding. Such books are simply inadequate as texts, for whatever their value may be to advanced graduate students and professionals.
3. Books on human abilities representing the information-processing approach whose coverage is motivated by the range of authors' interests rather than by an attempt to provide reasonably complete coverage of the human abilities field as it exists today. Used as texts, such books give an incomplete and even distorted view of current information-processing research on human abilities.
4. Books on human abilities that provide some elementary coverage of information-processing approaches to human abilities, but that seem based on the assumption that information-processing approaches to human abilities can be conveyed to the reader in the same way as psychometric approaches can be—namely, with a few paragraphs or even pages covering the "main theories" as they exist today. Such an assumption may have worked for psychometric theorizing, but it does not work for information-processing theorizing: Information-processing psychologists seek to understand in detail the cognitive bases of abilities that were named but not explained by psychometric theories. Thus, whereas it might be adequate to mention that a given psychometric theory postulates an ability called "verbal ability," one could do justice to information-processing theorizing about verbal ability only in the context of one or several chapters, because information-processing theorizing attempts to understand in detail the cognitive bases of verbal ability.

What, exactly, is an "information-processing" approach to human abilities? Different investigators will define such an approach in different ways, but

all seem to have in common the goal to understand the component processes, strategies, and mental representations of information, as well as interactions among processes, strategies, and representations that give rise to measured individual differences in abilities. All the chapters of this book seek to convey to the student just what the cognitive bases are of the various human abilities that have been identified but not thoroughly understood through psychometric and other kinds of analysis.

Obviously, this book is biased in its approach to, although I hope not in its coverage of, the range of human abilities. Although some of the chapters, and particularly the first chapter, review psychometric theories and research, no attempt is made to provide extensive coverage of this or many other approaches. There exist any number of texts that cover the psychometric approach in detail. Moreover, because there have been relatively few recent developments in this approach (at least as it is traditionally defined), I believe that any of a number of texts, not all of them recent, will provide adequate coverage of this approach. But I believe that this text is unique in providing extensive and intensive coverage of the human abilities field as seen from an information-processing point of view. Here, a new book is a must, because by far the largest share of the relevant research has been done in the last decade.

It is something of an oddity to present an "edited" text, but my decision to solicit contributions from top experts in the field rather than to write the book myself was a carefully deliberated one. Whereas the human-abilities field as seen from a psychometric point of view required detailed knowledge of a relatively small number of global theories, and of the machinery of factor analysis and other psychometric techniques, the human-abilities field as seen from an information-processing point of view requires detailed knowledge of a vast array of theories—some of them global and some of them quite specific—as well as of the experimental techniques of a wide range of subfields of cognitive psychology. I doubt there is anyone today who could claim the kind of wide-ranging expertise in the information-processing approach that could more easily be claimed by a number of individuals for the psychometric approach. In any case, I cannot claim such broad-ranging expertise. Hence, I decided to have each chapter cover a distinct information-processing ability and have it written by a distinguished expert on that ability. Although each chapter author could undoubtedly have written about other abilities as well, I doubt that such writing could be done with the authority and expertise that characterizes the individual's contribution to his or her primary area of endeavor. Thus, I have sought a quality in the chapters that I believe only a multiplicity of authors can provide. I, at least, believe that the quality I hoped for, as well as the elementary level of presentation I requested, have been attained.

This book is intended as an introductory text and is suitable for courses such as "Human Abilities," "Individual Differences," "Thinking," "Intelligence," and "Complex Information Processing." It might also be used as a

supplementary text in courses on cognitive psychology, tests and measurements, and educational psychology.

In sum, the authors and I offer this book as what we believe to be the first text on human abilities that provides a broad and balanced exposure to the field of abilities as seen from an information-processing point of view. We believe we have met a need that only a book such as this one could fulfill.

Robert J. Sternberg

CONTENTS

INTRODUCTION: WHAT IS AN INFORMATION-PROCESSING APPROACH TO HUMAN ABILITIES?

Robert J. Sternberg

This book's ten chapters present much of what we know about human abilities as viewed in terms of information processing. What, exactly, is an information-processing approach to human abilities? In this introduction, I will seek to describe just what such an approach is, and how it is similar to and different from other approaches, particularly, the so-called "psychometric" approach to abilities.

Information-processing psychology seeks to study the mind, in general, and intelligence, in particular, in terms of the mental representations and processes that underlie observable behavior. Information-processing researchers usually address five main points, as follows.

1. What are the mental processes that constitute intelligent performance on various tasks?
2. How rapidly and accurately are these processes performed?

3. Into what strategies for task performance do these mental processes combine?

4. Upon what forms of mental representation do these processes and strategies act?

5. What is the knowledge base that is organized into these forms of representation, and how does it affect, and how is it affected by, the processes, strategies, and representations that individuals use?

The information-processing approach to human abilities has arisen during the last 20 years as a response to the psychometric or differential approach to abilities. In this latter approach, psychologists sought to understand abilities largely in terms of factors, or mental structures, believed to be responsible for individual differences in observed performance on intelligence tests and in academic and other kinds of work (see Chapter 1). Information-processing psychologists were dissatisfied with the emphasis on structure in the psychometric approach. In particular, they wanted to find out more about the processes that underlie intelligent behavior, and they found psychometric theorists to be rather silent about what these processes might be. Information-processing psychologists have therefore seen their mission as different from that of psychometricians, with the latter emphasizing static structures, the former, dynamic processes. Indeed, the kinds of findings that have emerged from information-processing research and that are reported in this book are quite different from many of the findings that have emerged from the psychometric study of abilities. For example, psychometricians have started their investigations of human abilities with the study of individual differences among people, but information-processing psychologists have started their investigations with the study of how people perform on tasks; only then have they sought to look at individual differences in task performance. Whereas a psychometrician might be content to identify a factor (structure) of "human reasoning," information-processing psychologists would seek to identify the processes that underlie human reasoning.

Although many psychologists have tended to emphasize the difference between the two approaches, it is important to look as well at the similarities, both conceptually and historically.

Conceptually, both psychometricians and information-processing psychologists have investigated what it is that gives rise to observable individual differences in task performance. Much of the time, they have examined identical tasks, differing only in what aspects of task performance they feel ought to receive the lion's share of their attention. Moreover, both types of psychologists have attempted to construct theories of just what the basic human abilities are, and of how they are manifested in task performance.

Historically, many of the major psychologists identified primarily as "psychometricians" have also maintained a strong interest in the processes that underlie human abilities. For instance, Sir Francis Galton, an avid experimentalist, invented the correlational method, which underlies psychometric analyses of abilities. Alfred Binet invented the prototype for the most widely used

psychometric intelligence test, and yet a close reading of his writing will show that his often neglected theorizing was just as concerned with processing as any of the theories being proposed today. Charles Spearman invented factor analysis, which is the cornerstone of psychometric analyses of abilities; yet his 1923 treatise on the "principles of cognition" was a cognitive monograph, and provided the basis for much contemporary information-processing theorizing about abilities, particularly in the domain of inductive reasoning. Edward Thorndike is best known for his experimental work on animal learning, and yet was the author of a major book on the subject of psychometrically measured intelligence. Clark Hull, another famous learning theorist, wrote his first book on the subject of aptitude testing. Louis Thurstone, a psychometrician if ever there was one, advocated factorial methods as preliminaries to experimental ones, not as replacements for them. J. P. Guilford, clearly identified as a psychometrician, has proposed a theory of intelligence in which one of the three facets he believes crucial to intelligence describes the processes of intelligence. The list could go on and on, but I think the point should by now be clear: Psychometric and information-processing approaches to human abilities are largely complementary, and can be pursued in conjunction rather than as totally separate entities.

How do information-processing psychologists go about studying human abilities? In general, they analyze how people go about solving difficult mental tasks. They often construct explicit models of just how these tasks are solved. These models may take the form of computer programs, flow charts, or other schematizations of the flow of processing during task performance, but their goal is always to understand the processes, strategies, and mental representations that people use in task performance.

Although information-processing psychologists agree in their emphasis on mental processing, they disagree in just how this emphasis should be reflected in research on human abilities. Consider a brief sampling of the kinds of emphases and approaches that have characterized the research of information-processing psychologists.

1. *The cognitive-correlates method.* In this approach to understanding human abilities, subjects are tested on their performance of tasks that contemporary information-processing psychologists believe measure basic human information-processing abilities. Such tasks include, for example, the letter-matching task, in which subjects are asked to state as quickly as possible whether the letters in a pair such as "A a" constitute a physical match (which they don't) or a name match (which they do). Such researchers often use extreme-group designs, comparing high-ability and low-ability subjects (as identified by standard psychometric ability tests) in their performance of the basic information-processing tasks studied in the laboratories of information-processing psychologists.

2. *The cognitive-components method.* In this approach, subjects are tested on their performance of tasks of the kinds actually found on standard psychometric tests of mental abilities—for example, analogies, series comple-

tions, and syllogisms. The tasks studied tend to be more complex than those studied by cognitive-correlates researchers. Rather than starting from very simple tasks and building up to complicated tasks, cognitive-components researchers tend to start with more complicated tasks and work their way down to the simple processing components that generate performance on these more complicated tasks.

3. *Cognitive-training methodology.* This approach to understanding human abilities can be used in conjunction with either of the two preceding approaches or with some other approach. The idea is to study the trainability of cognitive processes, which is taken to indicate both the existence and the importance of these processes for performance on tests of mental abilities. Researchers using this methodology are interested not only in getting improvement on a single task in a single situation, but also in showing durability of training over time, and transfer of training from the task on which performance is trained to other similar tasks.

4. *Cognitive-content methodology.* This approach to understanding abilities seeks to understand differences in the contents and structures of the knowledge that higher- and lower-ability subjects bring to bear on cognitive tasks. Often experts in a given field of endeavor, such as chess or physics, are compared to novices in the field in order to discover the nature of the differences between the two groups in their knowledge bases, and in how they bring these knowledge bases to bear on problem solving.

Of course, these are not the only approaches that have been used by information-processing psychologists: the categorization is neither exhaustive nor mutually exclusive. But it does convey some sense of the variety of ways in which information-processing psychologists have sought to understand the nature of human abilities.

To conclude, then, information-processing psychologists seek to understand human abilities in terms of the basic mental mechanisms that underlie intelligent behavior. Their work is complementary to the work of psychometricians and others who have sought to study abilities in different ways. In this book, you will be introduced to what information-processing psychologists have discovered about the nature of human abilities. You should end up with a clear, basic grasp of the processes that underlie the main human abilities that have, during the last hundred years, been measured as part of research on the nature of human intelligence.

1

GENERAL INTELLECTUAL ABILITY

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General intellectual ability, or general intelligence, is among the most elusive of concepts. Certainly, few other concepts of any kind have been conceptualized in as many different ways. Although the emphasis in this book is on information-processing concepts of human abilities, I will here also discuss the psychometric view of abilities (which gave rise to IQ and other ability tests). It was because of dissatisfaction with this view that information-processing views have come to dominate contemporary theory and research on human abilities. In order to understand information-processing views, we must first understand psychometric views, and the ways in which they have been considered unsatisfactory.*

*Although these two views have probably been the most influential in forming North American and British concepts of the nature of intelligence, they are not the only views that have been advanced (see, e.g., Hebb, 1949; Hendrickson, 1982, for physiological views; and Piaget, 1972, for a genetic-epistemological view). These other views are not discussed here, but descriptions can be found elsewhere (see, e.g., Dockrell, 1970; Eysenck, 1982; Resnick, 1976; Sternberg, 1982b).

Before considering the information-processing view, and the psychometric view that gave rise to it, I would like to introduce you to one of the simpler ways to get some idea of what intelligence is: This way is to have experts or laypersons define the concept. Although such definitions are not likely to give us a detailed understanding of the nature of general intelligence, they may well give us some general, if vague, notions about just what it is that people mean by *intelligence.*

How People Define General Intelligence

The most famous study of experts' concepts of the scope of intelligent behavior was done by the editors of the *Journal of Educational Psychology,* in a symposium titled "Intelligence and its Measurement" in 1921. Fourteen experts gave their views on the nature of intelligence. Some examples of their definitions are as follows.

1. The ability to give responses that are true or factual (E. L. Thorndike).
2. The ability to carry on abstract thinking (L. M. Terman).
3. The ability to learn to adjust oneself to the environment (S. S. Colvin).
4. The ability to adapt oneself to relatively new situations in life (R. Pintner).
5. The capacity for knowledge and knowledge possessed (V. A. C. Henmon).
6. 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).
7. The ability to inhibit an instinctive adjustment, to redefine the inhibited instinctive adjustment in the light of imaginally experienced trial and error, and to realize the modified instinctive adjustment into overt behavior to the advantage of the individual as a social animal (L. L. Thurstone).
8. The ability to acquire abilities (H. Woodrow).
9. The ability to learn or to profit by experience (W. F. Dearborn).

There have been many, many definitions of intelligence since these were presented in the journal symposium, and an essay has even been written on the nature of definitions of intelligence (Miles, 1957). Certain themes seem to run through the definitions, such as the ability to learn from experience and to adapt to one's environment, but the perception of common themes is probably as much in the eye of the perceivers as in the minds of the experts. Clearly, it would be useful to have a nonarbitrary means of combining the perceptions of the various experts.

A contemporary version of this kind of study, and one that does provide a means of combining the concepts of various experts, was conducted by Sternberg et al. (1981). These investigators had many experts rate many kinds of behavior in terms of how distinctively characteristic each one was of intelligence

or how important it was for defining intelligence in an ideally intelligent person. The ratings were factor-analyzed, and the three factors that emerged—verbal intelligence, problem solving, and practical intelligence—were taken as characterizing experts' concepts of intelligence.

If we view intelligence as a cultural concept, then we may use laypersons' views as a way to specify the scope of a theory of intelligence. Consider some examples of such an approach.

Neisser (1978) collected informal data from Cornell undergraduates about their concepts of intelligence. More formal studies have been conducted by Cantor (1978), who asked adult subjects to list attributes of a bright person, and by Bruner et al. (1958), who asked people how often intelligent people display various personality traits. These authors found, for example, that intelligent people are likely to be characterized as clever, deliberate, efficient, and energetic, but not as apathetic, unreliable, dishonest, and dependent.

Siegler and Richards (1982) asked adult subjects to characterize intelligence in children of different ages. These subjects tended to conceive of intelligence as less perceptual-motor and as more cognitive with increasing age. Yussen and Kane (in press) asked children in the first, third, and sixth grades what their concepts of intelligence are. They found that older children's concepts were more differentiated than younger children's; that with increasing age, children increasingly characterized intelligence as an internalized quality; that older children were less likely than younger ones to think there are overt signs of intelligence; and that older children were less global than younger children in the qualities they associated with intelligence.

Wober (1974) investigated concepts of intelligence among members of different tribes in Uganda as well as within different subgroups of the tribes. Wober found differences in concepts of intelligence both within and between tribes. The Baganda, for example, tended to associate intelligence with mental order, whereas the Batoro associated it with some degree of mental turmoil. On semantic-differential scales, Baganda tribespeople thought of intelligence as persistent, hard, and obdurate, whereas the Batoro thought of it as soft, obedient, and yielding.

Serpell (1974, 1976) asked Chewa adults in rural eastern Zambia to rate village children on how well they could perform tasks requiring adaptation in the everyday world. He found that the ratings did not correlate with children's cognitive test scores, even when the tests that were used were adapted to seem culturally appropriate. Serpell concluded that the rural Chewa criteria for judgments of intelligence were not related to Western notions of intelligence.

Super (1982) analyzed concepts of intelligence among the Kokwet of western Kenya. He found that intelligence in children seemed to be conceived differently from intelligence in adults. The word *ngom* was applied to children, and seemed to connote responsibility, highly verbal cognitive quickness, the ability to comprehend complex matters quickly, and good management of interpersonal relations. The word *utat* was applied to adults, and suggested inventiveness, cleverness, and, sometimes, wisdom and unselfishness. A separate word, *kwelat,* was used to signify smartness or sharpness.

Sternberg et al. (1981) found that laypersons' concepts of intelligence are remarkably similar to those of experts. Characteristicness ratings by experts and by laypersons were correlated .96, and importance ratings were correlated .85. The two groups thus seem largely to agree about what behaviors are characteristic of intelligence and important in defining the ideally intelligent person. The views were not identical, however. First, the experts considered motivation to be an important ingredient of "academic" intelligence, whereas no motivational factor emerged in factor analyses of laypersons' ratings. Second, the laypersons seemed to emphasize the social-cultural aspects of intelligence somewhat more than the experts did.

Clearly, definitions of intelligence are just a start toward understanding what intelligence is. Such definitions tend to be vague and highly general. Moreover, there is no guarantee that people's informal notions are veridical representations of their intellectual abilities. Thus, such definitions are probably best seen as telling us "the lay of the land," and need to be followed up by more scientifically derived (formal) theories of the nature of intelligence. Such theories have been provided by both the psychometric tradition and the information-processing tradition in psychology.

Psychometric Theories of the Nature of Human Intelligence

Psychometric theories of intelligence (also called *differential* theories, because they are based on the study of individual differences between people) almost always attempt to understand intelligence in terms of a set of static latent sources of individual differences called *factors*. It is proposed that individual differences in intelligence-test performance can be decomposed into individual differences in these factors, each of which is posited to represent a distinct human ability.

Factors are hypothetical constructs intended to describe the underlying sources of individual differences that give rise to observed individual differences in test scores. To obtain factors, we would first give a set of individuals a large battery of tests; then we would compute the intercorrelations between scores on all possible pairs of tests. Now, our goal would be to reduce the scores on the tests to a smaller number of scores on the *factors* supposed to underlie performance on these tests. We would apply the technique of "factor analysis" to perform this reduction. Tests that tend to correlate highly (for example, vocabulary and reading comprehension) tend to group together into single factors. Tests that are only weakly correlated or uncorrelated tend to group into separate factors. For example, if we were to factor-analyze four tests—vocabulary, reading comprehension, arithmetical problem solving, and arithmetical concepts—we would probably obtain two factors, one of "verbal" ability and the other of "mathematical" ability.

Given that almost all differential theories use factors to understand intelligence, we might wonder how the differential theories differ from one another. The primary differences are in (a) the number of factors posited by the theory and (b) the geometric arrangement of the factors with respect to one another.

Consider how number and geometric arrangement can form the bases for alternative theories of intelligence.

Differences in Number of Factors

Differential theorists differ greatly in the number of factors they suppose to be important for understanding intelligent behavior. Indeed, the number of factors proposed in major theories ranges from 1 to 150.

At the lower end, Spearman (1927) proposed that intelligence comprises two kinds of factors, a general factor and specific factors. The ability represented by the general factor permeates performance on all intellectual tasks; the abilities represented by the specific factors each permeate only a single task, and so are not of much psychological interest. Hence there is just one factor of major psychological interest, the general factor, or *g*, as it has often been called. Spearman made two (not necessarily mutually exclusive) famous proposals about the nature of *g*. First, individual differences in *g* might be understood in terms of differences in the amount of mental energy that individuals could bring to intellectual task performance. Second, individual differences in *g* could be understood in terms of differences in people's abilities to use three "qualitative principles of cognition" (Spearman, 1923): apprehension of experience, eduction of relations, and eduction of correlates. In order to understand what each of these three principles represents, consider an analogy of the form *A* : *B* :: *C*:?; for example, *LAWYER* : *CLIENT* :: *DOCTOR* :?. Apprehension of experience refers to encoding (perceiving and understanding) each term of the analogy. Eduction of relations refers to inferring the relation between the first two analogy terms, here, *LAWYER* and *CLIENT*. Eduction of correlates refers to applying the inferred principle to a new domain, here, applying the rule inferred from *LAWYER* to *DOCTOR* to produce a completion for *DOCTOR* : *?*. The best-educated answer to this analogy would presumably be *PATIENT*. Given that analogies directly embody these principles, it is not surprising that Spearman (1923, 1927) and many others subsequently have found such analogies to be among the best available measures of *g*. (See Sternberg, 1977, for a review of relevant literature.)

In a more "middle-of-the-road" position, Thurstone (1938) proposed that intelligence comprises roughly seven "primary mental abilities." Consider the identity of each of these abilities, and how it is commonly measured.

1. *Verbal comprehension* is typically measured by tests of vocabulary (including both synonyms and antonyms) and by tests of reading-comprehension skills.
2. *Verbal fluency* is typically measured by tests that require rapid production of words. For example, the individual might be asked to generate as quickly as possible, and within a limited period of time, as many words as he or she can think of that begin with the letter *d*.
3. *Number* is typically measured by arithmetical word problems in which there is some emphasis on both computation and reasoning, but relatively little emphasis on extent of prior knowledge.