Part I

Introduction

Part I contains just a single chapter, "Conceptions of intelligence," presenting a review of past and present ideas about the nature of human intelligence. The chapter discusses two kinds of theories of intelligence: explicit and implicit. Explicit theories are the formal accounts of intelligence that are formulated by psychologists; implicit theories are the informal notions about intelligence that we carry around with us. Whereas explicit theories form the basis for most empirical research, implicit theories form the basis for our daily actions based upon our beliefs regarding the nature of intelligence. Because implicit theories, in a sense, give rise to explicit theories, it is important to understand both kinds of theories, how they are interrelated, and how they evolve. All of these issues are discussed in the introductory chapter.

1 Conceptions of intelligence

Intelligence is among the most elusive of concepts. Certainly, there are few other concepts that have been conceptualized in as many different ways. The various conceptions of intelligence that have been proposed have usually sounded related to each other; unfortunately, the nature and extent of the interrelations remain fuzzy. In this chapter, I discuss some of the alternative conceptions of intelligence that have been proposed in the past and attempt to clarify the nature of their interrelations.

Accounts of intelligence are of two basic kinds: explicit theories and implicit theories. Each of these kinds of theories will now be considered in turn.

Explicit theories of intelligence

Explicit theories of intelligence are based, or at least tested, on data collected from people performing tasks presumed to measure intelligent functioning. For example, a battery of mental ability tests might be administered to a large group of people and the data from these tests analyzed in order to isolate the proposed sources of intelligent behavior in test performance. Although investigators proposing explicit theories might disagree as to the nature of these sources of intelligence – which might be proposed to be factors, components, schemata, or some other kind of psychological construct – they would agree that the data base from which the proposed constructs should be isolated ought to consist (directly or indirectly) of performance on tasks requiring intelligent functioning.

Explicit theories of intelligence come in a variety of forms. I will discuss here the two forms of theorizing that have been the most influential in the psychology of human intelligence – differential theorizing and cognitive theorizing. Although these two views have probably been the most influential ones in North American and British conceptions of the nature of intelligence, they are not the only views that have been advanced (see, e.g., Hebb, 1949, and Hendrickson, 1982, for physiological views and Piaget, 1972, for a

genetic – epistemological view). These other views are not discussed here, but descriptions of these and other views can be found elsewhere (see, e.g., Dockrell, 1970; Eysenck, 1982; Resnick, 1976; Sternberg, 1982c).

Differential theories of the nature of human intelligence

Differential (or psychometric) theories of intelligence, so called because of their bases in the study of individual differences among people, have in common (with rare exceptions) their attempt to understand intelligence in terms of a set of underlying abilities – for example, verbal ability, reasoning ability, and the like. These underlying abilities are identified through a mathematical technique called factor analysis. This technique starts with a matrix of intercorrelations (or covariances) for a set of tests and identifies "latent" sources of underlying variation in test scores that are theorized to give rise to the observable variation in test scores. These latent sources of individual differences are called factors. Thus, it is proposed that individual differences in performance on intelligence tests can be decomposed into individual differences in these factors, each of which is posited to represent a distinct human ability.

Given that the large majority of differential theories have in common the use of factors as a basis for understanding intelligence, one might wonder how the differential theories differ from one another. The primary differences are in terms of (a) the number of factors posited by the theory and (b) the geometrical arrangement of the factors with respect to one another. Consider how number and geometrical arrangement can form the bases for alternative theories of intelligence.

Variation in number of factors. Differential theorists vary greatly in the number of factors they purport to be important for understanding intelligent behavior. Indeed, the range in numbers of factors for major theories is 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; each of the abilities represented by the specific factors permeates only a single task, and hence these abilities are not of much psychological interest. Thus, 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 regarding the nature of *g*. One proposal was that individual differences in *g* might be understood in terms of differences in the levels of mental energy individuals could bring to intellectual task performance. The other proposal was that individual differences in *g* could be under-

stood in terms of differences in people's abilities to utilize 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 of the given terms of the analogy. Eduction of relations refers to inference of the relation between the first two analogy terms, here, LAWYER and CLIENT. Eduction of correlates refers to application of the inferred principle to a new domain, here, applying the rule inferred from LAWYER to CLIENT so as to produce a completion for DOCTOR : ?. The best 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 analogies such as the one above to be among the best available measures of *g*. (See Sternberg, 1977b, for a review of relevant literature.)

In a more "middle-of-the-road" position, one finds Thurstone (1938), who 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.* This ability is typically measured by tests of vocabulary (including both synonyms and antonyms) and by tests of reading comprehension skills.

2. *Verbal fluency.* This ability 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.* This ability is typically measured by arithmetic word problems where there is some emphasis upon both computation and reasoning, but relatively little emphasis upon extent of prior knowledge.

4. *Spatial visualization.* This ability is typically measured by tests requiring mental manipulation of symbols or geometric designs. For example, the individual might be shown a picture of a geometric design in some degree of angular rotation, followed by a set of pictures in various orientations that are either identical (except for degree of rotation) to the original object or else are mirror images of the original objects. The individual would have to indicate whether each item is the same as the target or instead is a mirror image.

5. *Memory.* This ability is typically measured by a test of recall-memory for words or sentences or by paired-associates recall of names with pictures of people. A typical paired-associates test would present people with a set of pictures paired with the names of the people they depict. The people would be given some fixed amount of time to study the set of pictures and names.

After time was called, the people would be presented with the pictures and be asked to provide the name corresponding to each picture.

6. *Reasoning*. This ability is typically measured by tests such as analogies (e.g., LAWYER : CLIENT :: DOCTOR : ?) and series completions (e.g., 2, 4, 7, 11, ?).

7. *Perceptual speed*. This ability is typically measured by tests requiring rapid recognition of symbols – for example, rapid crossing-out of *l*'s that are embedded in a string of letters.

At the upper extreme in terms of number of proposed factors is Guilford (1967; Guilford & Hoepfner, 1971), who at one time proposed that intelligence comprises 120 distinct factors and has more recently increased this number to 150 (Guilford, 1982). According to Guilford, every mental task involves three ingredients: an operation, a content, and a product. There are five kinds of operations: cognition, memory, divergent production, convergent production, and evaluation. There are five kinds of contents: visual, auditory, symbolic, semantic, and behavioral. And there are six kinds of products: units, classes, relations, systems, transformations, and implications. Since the subcategories are independently defined, they are multiplicative, so that there are $5 \times 5 \times 6 = 150$ different mental abilities.

Guilford and his associates have devised tests that measure many of the factors posited by the model. As of 1982, Guilford claims to have demonstrated the existence of 105 of the 150 possible factors. Guilford (1982) has also made clear that, although the 150 factors are logically independent, they can be psychologically dependent in the sense of being intercorrelated. Consider how just a few of these abilities are measured. Cognition of visual relations (called cognition of figural relations in the 1967 version of the model) is measured by tests such as figure analogies or matrices. Memory for semantic relations is measured by presenting to examinees a series of relationships, such as "Gold is more valuable than iron," and then testing retention in a multiple-choice format. Evaluation of symbolic units is measured by same–different tests, in which subjects are presented with pairs of numbers or letters that are identical or different in minor details. Subjects are then asked to mark each pair as "same" or "different."

Variation in geometric structure of factors. As noted earlier, two models positing the same number of factors – and even the same contents for factors – might still differ because of their positing of different geometric arrangements of these factors. The four best-known structures are an unordered arrangement, a cubic arrangement, a hierarchical arrangement, and a radex arrangement.

Unordered arrangements consist of lists of factors all of which are asserted to be equal in importance to each other. Thurstone's (1938) primary mental

abilities might be seen as a good example of this kind of arrangement. Thurstone suggested simply that intelligence could be understood in terms of seven factors. They are not ordered in any particular way: Any permutation of the list is as valid as any other.

The best-known "cubic" theorist is Guilford. Guilford (1982) has represented the structure of intellect as a large cube composed of 150 smaller cubes. Each dimension of the cube corresponds to one of the three categories (operation, content, product), and each of the 150 possible combinations of the three categories forms one of the smaller cubes.

Hierarchical arrangements are probably most popular in the contemporary differential literature on intelligence. According to this kind of view, abilities are not of equal importance. Rather, certain abilities are more global, and hence more important, than others. Spearman's (1927) factorial model, with a general factor and less important specific factors, might be seen as the original hierarchical model, although it is not clear that Spearman thought of his theory primarily in this way. Holzinger (1938) elaborated upon Spearman's point of view by suggesting that there exist group factors intermediate in generality between the general factor and the specific factors. These group factors permeate performance on some class of tasks (and in any case, more than one task), but are not involved in performance of all mental tasks in a given test battery. Burt (1940) proposed a five-level hierarchical model, with the "human mind" at the top, the "relations level" right below it, associations below that, perceptions below associations, and sensation at the bottom of the hierarchy. Vernon (1971) proposed a more sophisticated hierarchical model, suggesting that *g* could be decomposed into two broad group factors, verbal–educational ability and practical–mechanical ability. He further proposed that these broad group factors could be further decomposed into narrower group factors, although this further decomposition is of less interest in his theory.

Finally, Guttman (1965) has proposed a radex structure for intelligence. A radex can be thought of as a circle. Each test found on intelligence test batteries can be placed somewhere in the circle. Tests nearer the center of the circle measure abilities more "central" to intelligence. Thus, the purest measures of intelligence would be at the center of the circle, and the least pure measures would be at the periphery of the circle. Arrayed around the interior of the circle are differing kinds of task contents and required processes – for example, verbal tasks, numerical tasks, and geometric–pictorial tasks.

Critique. In sum, differential or psychometric theories of intelligence differ primarily in terms of the numbers of factors they posit and in terms of the geometric arrangements of these factors. On their face, the theories seem

quite different. It is not clear that at a deeper level these differences are as consequential as they initially would seem. Indeed, the amount of agreement among these theories could be seen as substantially greater than the amount of disagreement.

First, the theories share common metatheoretical assumptions. All assume that intelligence can be understood in terms of latent sources of individual differences or "factors." These factors are believed to provide, in some sense, a "map" of the mind. Because the factors are identified on the basis of observed individual differences in mental-test performance, all of the theories assume that the primary basis for identifying the dimensions of intelligence ought to be observed individual differences. Also, the kinds of tests that have served as the bases for measuring these individual differences have been quite similar. All are in the tradition of Binet and Simon (1905, 1908), although they differ in the details of exactly what skills they measure.

Second, the alternative theories are, in many cases, mathematically nearly equivalent. One might wonder how such different factor structures could result from essentially the same mathematical technique, factor analysis, being applied to roughly comparable sets of subjects taking roughly comparable sets of tests. The answer lies largely in the placement of axes in a "factor space." Factors can be represented in a space, where each factor is a dimension in the space. When a factor analysis is performed, the locations of points (tests) in the factor space are fixed, but the locations of the factor axes are not. In other words, it is possible to have many – indeed, infinite – orientations of factor axes. It turns out that many of the theories differ from one another primarily in terms of orientation of the factor axes in the factor space and hence are (roughly) equivalent mathematically. From this point of view, the different theories say the same things in different ways. Recent cognitive–experimental research suggests that the various factorial theories can all be mapped into a common set of information-processing components of task performance (Sternberg, 1980c, 1980f). In other words, no matter what factor structure one uses, the basic processes contributing to the factors are the same. This point of view will be elaborated later in the book.

Third and finally, some of the differences among theories appear, on closer examination, to be ones of emphasis rather than of substance. For example, Spearman's and Thurstone's theories appear to be radically different. But by the end of his career, Spearman was forced to concede the existence of group factors; indeed, he even collaborated with Holzinger on the development of a theory that encompassed group factors as well as the general and specific ones. Similarly, Thurstone was forced, by the end of his career, to acknowledge that a higher-order general factor existed that in some sense incorporated the primary mental abilities. The primary evidence for such a higher-order factor is that the primary mental abilities are not statistically independent, but rather are intercorrelated with each other: People who

tend to be high in one ability tend to be high in others as well, and people who tend to be low in one ability tend to be low in others as well. When one factors these factors, one obtains a general, higher-order factor. The main difference between Spearman and Thurstone may thus have been in the emphases they placed on higher- versus lower-order factors. Spearman emphasized the former, Thurstone the latter. Humphreys (1962) and Jensen (1970) have provided excellent accounts of how hierarchical models can be formed that incorporate the ideas of factors both at the level of Spearman's general factor and at the level of Thurstone's primary mental abilities.

There have been what at times have seemed like unending debates over the merits of factor analysis as a means for uncovering the nature of intelligence. (See, e.g., Burt, 1940; Eysenck, 1953, 1967; Humphreys, 1962; Royce, 1963, 1979; Sternberg, 1977b, 1979b.) I have come to view these debates as misconceived, in large part because it really does not make sense to evaluate a methodology independent of its use. To the extent one's goal is to isolate rather global, structural constellations of individual differences in test performance, factor analysis certainly can be useful. As so often happens with multivariate methods, this method has been subjected at times to fairly serious misuse (cf. Guilford, 1952; McNemar, 1951; Sternberg, 1977b, for discussions of some of these misuses). When a method is subjected to misuse, it is tempting to blame some intrinsic property of the method rather than to blame the misusers. To the extent that there has been a generalized and serious misrepresentation, it is perhaps in claiming too much for what factor analysis has told us about intelligence. More attention should have been paid to a careful accounting of just what questions about intelligence factor analysis can and cannot answer (see Sternberg, 1980f). But the same could be said for many other methods as well. When a method is first applied to the study of a problem, it is quite natural for overly strong claims to be made: The limitations of the method simply have not yet become clear. But over the years, these limitations do become more clear, and it is necessary to pay attention to both strengths and weaknesses of the method as applied to various kinds of problems. In the case of factor analysis, it was certainly useful in providing initial structural models, and recent uses of confirmatory factor analysis (e.g., Frederiksen, 1982; Geiselman, Woodward, & Beatty, 1982) demonstrate that factor analysis will continue to play an important role in understanding the nature of intelligence. We even have, at this time, some fairly clear notions as to what this role is likely to be, but a full discussion of this topic is beyond the scope of this book.

Cognitive theories of the nature of human intelligence

Cognitive (or information-processing) theories of intelligence have in common their attempts to understand human intelligence in terms of the mental

processes that contribute to cognitive task performance. A primary difference among views is in the level of cognitive functioning that they emphasize in attempting to seek this understanding. At one extreme, there exist investigators who have proposed to understand intelligence in terms of sheer speed of information processing and who have used the most simple tasks they could devise in order to measure pure speed uncontaminated by other variables. At the other extreme, there exist investigators who have studied very complex forms of problem solving and who have deemphasized or discounted speed of functioning in mental processing. In general, greater emphasis upon speed of processing has been associated with investigators studying the simpler forms of information processing, whereas greater emphasis upon accuracy of and strategies in information processing has been associated with investigators studying the more complex forms of processing. Consider a sampling of the range of levels of processing that have been studied. Again, no claim is made for the completeness of this survey, although it does seem to be fairly representative of the kinds of work that have been done.

Pure speed. Proponents of the notion that individual differences in intelligence can be traced back to differences in sheer speed of information processing have tended to use simple reaction time and related tasks in order to make their point. In a simple-reaction-time paradigm, the subject is required simply to make a single overt response as quickly as possible following presentation of a stimulus. This paradigm has been widely used, ever since the days of Galton, as a measure of intelligence (Berger, 1982). Although Galton (1883) and Cattell (1890) were strong supporters of the importance of sheer speed in intellectual functioning, the levels of correlation obtained between measures of simple reaction time and various standard measures of intelligence, none of which are perfect in themselves (e.g., IQ test scores, school grades, and the like), have been rather weak. Wissler (1901) obtained correlations close to zero, as did Lemmon (1927). Lunneborg (1977) obtained correlations with eight psychometric measures of intelligence ranging from -.17 to -.42, with a median of -.38. (Negative correlations would be expected because longer reaction times are presumed to be associated with lower levels of intelligent performance.) In my view, some of the most trustworthy results are those attributable to Jensen (1980, 1982), who has reported correlations for two samples: One of the correlations was in the middle -.20s, the other around .10. Clearly, if there is any relationship at all between measures of pure speed and of psychometrically measured intelligence, the relationship is a weak one.

Choice speed. A complication of the above view is that intelligence derives not from simple speed of processing, but rather from speed in making

choices or decisions to simple stimuli. In a typical "choice-reaction-time" paradigm, the subject is presented with one of two or more possible stimuli, each requiring a different overt response. The subject has to choose the correct response as rapidly as possible following stimulus presentation. Correlations with psychometric measures of intelligence have been somewhat higher than those obtained for simple reaction time (Berger, 1982). Lemmon (1927) found a correlation of -.25 between choice reaction time and measured intelligence. Lunneborg (1977) found variable correlations. In one study, correlations ranged from -.28 to -.55, with a median of -.40. In a second study, however, correlations were trivial. Jensen (1982) reported a correlation of -.3 for one sample, but a correlation close to zero for another. Lally and Nettelbeck (1977) obtained a correlation of -.56, but in a sample with a very wide range of IQs (57 – 130); such samples tend to boost correlations.

An interesting finding in the research both of Jensen (1979, 1982) and of Lally and Nettelbeck (1977) is that the correlation between choice reaction time and IQ tends to increase with the number of stimulus – response choices involved in the task. In fact, these investigators found a roughly linear relation between the level of correlation obtained and the log to the base 2 of the number of choices (bits) in the task, at least through eight choices (three bits). But the correlations for typical ranges of subject ability nevertheless seem to peak at slightly over the -.4 level. Thus, increasing the number of choices in a choice-reaction-time task seems to increase correlation with IQ, but the task still is a long way off from providing what would seem to be a causal account of individual differences in psychometrically measured IQ.

Speed of lexical access. Hunt (1978, 1980) has proposed that individual differences in verbal intelligence may be understood largely in terms of differences among individuals in speed of access to lexical information in long-term memory. According to this view, individuals who can access information more quickly are able to profit more per unit time of presented information and hence to perform better on a variety of tasks, especially verbal ones. Hunt, Frost, and Lunneborg (1973) and Hunt, Lunneborg, and Lewis (1975) initiated a paradigm for testing this theory that makes use of the Posner and Mitchell (1967) letter-comparison task. Subjects are presented with pairs of letters – such as *AA, Aa,* or *Ab* – that may be the same or different either physically or in name. For example, *AA* contains two letters that are the same both physically and in name; *Aa* contains two letters that are the same in name only; and *Ab* contains two letters that are the same neither in name nor in physical appearance. The subject's task is to indicate as rapidly as possible whether the two letters are a match: In one condition, subjects indicate whether or not the letters are a physical match; in another condition, the same subjects indicate whether or not the letters are a name