INTELLIGENCE

THE PSYCHO-METRIC VIEW

PAUL KLINE

Intelligence

The psychometry of intelligence is one of psychology's great achievements yet it is poorly understood. Paul Kline's latest book provides a modern, readable introduction to the subject. Written to be clear and concise it none the less provides a rigorous account of the psychometric view of intelligence.

Professor Kline explains factor analysis and the construction of intelligence tests and shows how the resulting factors provide a picture of human abilities. He shows the value of such tests in both applied and theoretical psychology and in so doing answers the critics of intelligence testing. It is one of the few modern texts that deals with the factorial view yet includes modern work in the cognitive field.

The book will be of interest to students of psychology and education, to those taking courses in clinical, educational and occupational psychology, *as well as* those in psychological testing itself.

Paul Kline is Professor of Psychometrics at the University of Exeter. He is one of the leading authorities in the field. His recent books include *A Handbook of Test Construction* and *Psychology Exposed.*

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Preface

The purpose of this book is to restate the psychometric view of intelligence which, for a variety of reasons, intellectual and social, has fallen into obscurity. Intellectually the rise of cognitive psychology and cognitive science has caused psychologists to stress processes of thinking and to regard intelligence as a somewhat useless, global label. Among the social factors which have led in some cases to direct attacks on the concept of intelligence are the generally egalitarian zeitgeist, claims that intelligence testing leads to racial discrimination or even reflects it, and the unmasking of one of the leading practitioners of intelligence testing, Sir Cyril Burt, as a fraud.

In addition to this the notion of intelligence as even a partly heritable characteristic is ill at ease in Thatcherite society where failure to succeed is regarded as a moral flaw, hard work and determination being the necessary ingredients. This accords well with the views at the other end of the political spectrum where failure is seen as resulting from the oppression and enslavement of the poor by the rich.

In this book I try to put the record straight and present the latest psychometric findings concerning the nature of intelligence and other human abilities. I am encouraged in this endeavour by the fact that in the real world, beyond the narrow boundaries of academic psychology, intelligence tests and other psychometric methods of assessment are being used in ever greater numbers as employers seek to find people best suited to their jobs. The application of psychometrics is one of the few technological successes in psychology and it is right that students and practitioners should understand the theoretical bases of this work. In addition to this a knowledge of the psychometrics of ability is valuable for a wider understanding of the psychology of human development and achievement.

Chapter one

The meaning of intelligence

In this chapter I shall discuss the meaning of intelligence as it is generally used in English. This definition will be compared with that given it by psychologists. Finally I shall examine the status of intelligence as a concept since it has been argued that it is simply redundant and hence deleterious for the scientific study of human abilities.

As Jensen (1980) has pointed out, the notion of intelligence can be found in the great texts of the Hindus and the Ancient Greeks. This is hardly surprising since in almost every activity we can see things being done intelligently and otherwise. Intelligence is popularly defined as the ability to learn, understand and deal with novel situations. The intelligent person is seen as quick-witted, acute, keen, sharp, canny, astute, bright and brilliant, to select just a few of the relevant adjectives in everyday language. At the other end of the scale the unintelligent person is described as dim, dull, thick, half-witted or stupid. These adjectives give the flavour of intelligence as the word is used in English.

An example, perhaps, will bring the concept to life. The philosopher Bertrand Russell illustrated most of these characteristics to a very high degree. When he spoke on a subject, however complex, he was wonderfully lucid, picking out the essentials of the problem. His arguments were clear and convincing. His replies to objections were almost always devastating. He could instantly see the flaws and errors in reasoning and arguments. His superb intelligence, indeed, was the basis of his *Principia Mathematica* (Russell, 1911).

Now this example highlights some other important points about intelligence. Russell was distinguished for the analytic quality of his reasoning and his quickness at seeing the point. This is quite different from massive learning and prodigious memory, although these may be found together. In universities there reside many scholars who are hugely knowledgeable, in their fields, but are not highly intelligent in the sense discussed above. In my view it is such individuals who bring learning and scholarship into disrepute. The unintelligent scholar simply flounders in a sea of facts and contributes little to the world. The scholars we remember combine intelligence and learning.

I think it is clear, from these introductory paragraphs, how the term intelligence is conceptualised in English. Psychological definitions, although they attempt precision, are highly similar although some are remarkably uninformative. In an effort to be comprehensive, for example, Brown (1976) writes 'intelligence, to the psychologist, is the ability to perform certain types of task'. Without specifying those tasks this is not satisfactory. This definition is similar to that given by Boring (1923) who claimed that intelligence is what intelligence tests measure. This is not so circular as it first appears since, as will be discussed in later chapters of this book, psychometrists are able to specify empirically what intelligence tests do measure. Some psychologists have attempted more precise definitions, for Boring simply changed the problem into having to define what intelligence tests measure. Terman, the author of one of the best known intelligence tests, the Stanford-Binet test, defined it as the power to think abstractly, to be self-critical and to be adaptive. Wechsler (1975), the constructor of the WAIS and WISC tests, defined intelligence as the capacity of a person to understand the world and meet its demands, a definition which is remarkably similar to the common English usage. Humphreys (1975) has defined intelligence as our repertoire of intellectual skills. However, this again throws the definition back – to the meaning of intellectual skills.

Several points about this sample of definitions by psychologists deserve comment. First there is no clear agreement. Thus a dictionary of psychology could offer no simple definition. Despite this there is some concurrence, namely that intelligence is a capacity of some kind that is useful in problem solving. In this respect, as I have argued, it is little different from the common-sense definition. Such a general and rather diffuse definition is hardly suitable for scientific study and I now want to turn to definitions that are not just verbal but are more experimental and empirical. These are part of the branch of psychology known as psychometrics, measuring the soul. Would it could be done. This is an aspect of psychology which originated in Great Britain and in which intelligence was a fundamental concept. I should point out, at this point, that in many branches of science purely verbal definitions are not useful. For example it would be possible to decide arbitrarily to define intelligence as abstract reasoning ability. However, if it were the case that, in the real world, intelligence, as it was used, was more than this component, such a definition, no matter how consensual, would be useless. This is simply definition by fiat which in empirical science will never do as exemplified in astronomy by claims that the earth was flat and that the sun went round the earth.

In this book I intend to explicate this psychometric concept of intelligence which often now lies neglected, despite the formidable research which underpins its claims. As a beginning I shall discuss the psychometric definition but before this can be done I shall have to make some general points about psychometrics and its methods.

Essentially psychometrics was the invention of Spearman at the turn of the century in University College London. His paper '"General intelligence": objectively determined and measured', published in the *American Journal of Psychology* in 1904 contains all the basic psychometric reasoning about the nature of intelligence. In discussing this pioneering work the psychometric definition and concept of intelligence will become clear. The question Spearman asked was this: why is it that human abilities are positively correlated, that is why is there a general tendency for those who are good at one thing to be good at others? This is the phenomenon that teachers refer to as correlation not compensation. It is, alas, not the case that the dimwit at maths is good at woodwork. The simple answer, and as it has turned out too simple, as will be fully discussed in later chapters of this book, was that this correlation could be accounted for by general intelligence or *g*. This *g* was common to all tasks requiring ability, hence the correlation. For example ability at French depended upon *g* plus a specific French component; physics depended upon *g* plus a physics component and so on. Spearman's achievement was to invent a statistical method, factor analysis, which could uncover this structure of abilities.

Later psychometrists, right up to the present day, have, in fact, developed this approach. Factor analysis has been extensively improved and made more efficient and this technique will be fully described in Chapter 2. Far more abilities have been sampled and the empirical nature of the *g* factor or factors has been explored in the clinical, educational and industrial fields. In addition there has been considerable theorising about its nature and all these results can be found in the relevant chapters of this book. Suffice it to say now that in psychometry, intelligence is equated with this general ability or *g* the factor common to all problem-solving abilities. Since the best intelligence tests are deliberately constructed to measure this *g* factor it does make sense to define intelligence as what intelligence tests measure, provided that the *g* factor can be specified.

The nature of the *g* factor

Modern factor analysis (Cattell, 1971) has broken the *g* factor into two: crystallised and fluid intelligence. Fluid intelligence is the basic reasoning ability of an individual dependent, to a large extent, on the neurology of her brain. Crystallised intelligence represents this ability as it is evinced in the skills valued by the culture in which the individual lives. In the West, therefore, fluid ability is invested in science and technology and not at all in hunting and tracking, to give a cross-cultural example. Factor analysis, as will be discussed in later chapters of this book, has revealed the extent to which these *g* factors are implicated in different tasks and occupations. Skill in all activities which demand problem solving is correlated with *g*, highly in some cases but less so in others. Nevertheless the relationship is always positive. This is the broad, general picture of intelligence as conceptualised in psychometrics. However, there have been many objections to this psychometric concept and the most important of these will be discussed briefly in this introductory chapter.

A recent objection to the factor analytic work in human intelligence has been raised by cognitive psychologists, for example Hunt (1978), Carroll (1983) and Sternberg (1977). This concerns the utility of the *g* factor or factors. Even if it is admitted that a common factor can be found in many problem-solving tasks, labelling it as *g*, or reasoning ability, or any other descriptor, does not explain it. The cognitive processes involved in problem solution are not thereby understood. At best the factor is descriptive. What is necessary, therefore, is a study of the processes employed in problem solution. This is an important point and in Chapter 9 modern work, where the factor is explicated experimentally, will be discussed. However, it must be pointed out here that this research is an extension of the factor analytic work, not a replacement, and could not take place at all if ability factors had not firmly been established. Certainly the main researchers in factor analysis, such as Cattell, Guilford and Eysenck, regard such studies as essential parts of their research programmes (Eysenck, 1982).

The second important objection concerns the status of intelligence as a concept. Miles (1957) has argued in the behaviourist tradition that intelligence is a redundant concept. We say, the argument runs, that someone is behaving intelligently because he has a lot of intelligence. This is, however, a circular argument because the only evidence that intelligence exists comes from the observation of intelligent behaviour. This argument has been widely applied to the notion of all psychological entities by Skinner (1953). However, it will not do. Intelligence can be measured independently by tests and the scores can be used to predict a disparate variety of outcomes in both the educational and occupational spheres, as will be fully discussed in later chapters of this book.

An example will clarify the point. If I required a number of people to learn Classical Greek to a high standard within a few months, I would select those who performed well on a test of *g* such as Raven's Matrices (Raven, 1965c), a test which is heavily *g* loaded and which consists of sequences of patterns which have to be completed. This test has nothing in common, it will be noted, with Greek, in respect of content. I use intelligence as an explanation of their superior performance at Greek, compared with moderate scorers on the test. This use of an explanatory concept, such as intelligence, which can be measured, is no different from the use of concepts in other sciences. An analogy can be found in the case of deafness. It is perfectly sensible to explain an individual's failure to learn well in school by invoking deafness as a cause. The fact is that there is no error in the proposition of abstract constructs if they can be measured independently of the observations which they are meant to subsume. This, however, is not to deny that it could be valuable to investigate cognitive processes underlying intelligence, as has been discussed. Finally, it must be pointed out that the status of intelligence as an explanatory concept in this example does not stand or fall by the fact of a low or high correlation with Greek. If the correlation is low then the explanation is wrong. My point here is simply that the status of intelligence as an explanatory concept is perfectly respectable.

Howe (1988) has attempted to demonstrate, by surveying a variety of claims about intelligence, that it is an empty concept. Some of these are relatively trivial and I shall say nothing about them. Some of the arguments are important and I shall scrutinise these briefly. One of the difficulties in analysing these arguments lies in the vagueness of the language. For example he asks whether level of intelligence is controlled by inherited mechanisms? But what would constitute a positive answer? Genes are either implicated or not. Later he writes 'the view that knowledge that a hereditary cause of variability in human intelligence may exist must provide any strong clue to the precise direction of form of that cause is quite wrong.' This is indeed unanswerable because the meaning of 'precise direction of form of that cause' is unclear. Indeed it seems empty of sense. The next sentence is no better: 'it has been supposed that any effects of genetic factors would need to be exerted via the kinds of physiological processes that determine the power, speed or flexibility of physiological processes underlying cognition . . .' This he claims is wrong. However, why should there be processes underlying processes in the first place? Why could the action not be direct? This argument seems to be loose in the extreme. Howe continues 'for instance hereditary factors could exert their mark on intelligence by affecting motivational processes of some kind or personality variables . . . or sensory perception.' These arguments, while possible, are empirically false as the extensive work of Cattell in the field of motivation, personality and ability demonstrates. Personality and motivational factors are independent of the ability sphere (Cattell, 1981). There can be no question here that Howe has failed to make his point. In a later chapter the work on the hereditary determination of the *g* factors will be examined.

As a final riposte Howe argues that the extraction of a factor from a set of intellectual tests tells us little if anything about the causes of intellectual variability. No defence of this extravagant claim is offered and in the following chapter where the rationale and methods of factor analysis are set out, it will become obvious that this view is mistaken. Similarly the arguments used by Alice Heim (1975), who was a brilliant constructor of intelligence tests, in connection with the unreliability of factor analytic solutions, will be dealt with in this chapter. Suffice it to say here, that modern factor analyses can be made highly reliable and replicable.

From the introductory discussion of this first chapter, I hope it is clear that the psychometric concept of intelligence which I shall explicate in detail in the remaining chapters of this book is similar to that in common English usage. It can be roughly seen as a general reasoning capacity useful in problem-solving tasks of all kinds. Objections concerning its redundancy and its lack of explanatory power have been shown to be ill conceived and without force. Other objections which have been raised about psychometric *g* will be discussed in the relevant chapters of this book.

Chapter two

Factor analysis

In this chapter I shall attempt to set out the rationale and method of factor analysis so that it can be properly understood. The emphasis will not be upon the algebra or computation (which in any case are now the province of the computer and which in their refined form give little indication of their logic and meaning other than to fine mathematicians). Rather I shall concentrate upon the logic and function of factor analysis and upon the meaning of the technical terms which have to be used to describe the results. Factor analysis is open to many abuses of logic and sense all of which can be found in published reports now that any social scientist, however innumerate, can use the method. All these errors of method and interpretation will be discussed. Without this the psychometric concept of intelligence and human abilities in general cannot be grasped and there can be no doubt that many of the objections which have been raised against psychometric work are ill founded on account of just such misunderstandings.

Before I begin this explication of factor analysis, for those readers who require a clear account of all the computational procedures of the different methods, Cattell (1978) and Harman (1976) can be recommended. Child (1970) is useful because his is the most simple account of some of the computational methods.

Definition of terms in factor analysis

First I shall define the terms of factor analysis because, without this, discussion is hopelessly rambling. I shall begin with some basic statistical definitions.

Variable

Any characteristic on which individuals or the same individual over time can vary. Height, weight and test scores are obvious examples.

Variance

This is the variation in scores on a variable of a sample or population. Sample and population must be distinguished. If we are studying reading among 10-year-old children in Great Britain the population consists of all of these children. In almost all research we are forced to use samples and it is important that these samples are representative of the populations which they purport to represent. As we shall see sampling is important in factor analysis.

Correlation

The correlation coefficient, *r*, indicates the degree of agreement between two sets of scores. If high scores on one variable are associated with high scores on the other the correlation is positive, as is the case with all human abilities. If high scores on one variable are associated with low scores on the other, the correlation is negative. The correlation coefficient runs from 1 to minus 1. A correlation of 1 indicates perfect agreement, minus 1 the opposite, for example if the order of one variable was a perfect inversion of the other. A correlation of 0 shows that agreement between the variables is random, that is there is no relationship at all.

Meaning and interpretation of correlations

If we square a correlation coefficient it indicates the amount of variance in common between the two sets of scores. Thus a correlation of 0.8 shows that there is 64 per cent of variance in common on the two variables. However, this figure still requires some interpretation if it is to be given any psychological meaning. There are various determinants of correlations and these will now be discussed.

Common elements may be one cause of a substantial correlation. For example there is a high correlation between scores on Latin and Greek. This is because there are similar abilities involved in both tasks. High *g* is important to understand the grammatical rules; verbal ability is required for both, especially in elegant translations. In addition there is a common element of interest in the academic questions of the ancient world, in contrast, say, to the vocational aspirations of trainee accountants.

A cause common to both variables may account for the correlation. For example there is a correlation between cigarette smoking and lung cancer. Eysenck (1980), however, has maintained that this is accounted for by a third factor which causes an individual to smoke and to be liable to lung cancer. This is a possible interpretation of the correlation and it highlights an important point that is often ignored. Causation cannot be inferred from correlation. Since the Second World War there is a correlation between imports of luxury goods and increases in the mean height of adults in Great Britain. This, however, results from increases in prosperity for the mass of the population and is clearly not causal.

Magnitude of correlations

The magnitude of a correlation reflects the degree of variance in common between two sets of scores. However, this can be affected by what are essentially distorting variables. Two factors are particularly influential and must always be borne in mind when scrutinising correlations. Since correlations are the basis of factor analysis this may also be similarly distorted. Correlations can be reduced in size by homogeneity of variance. If we take the correlation between intelligence and academic success across the whole range of ability it is likely to be substantial, around 0.5. However, this would include those of such low intelligence that they cannot read or write and would, necessarily, score 0 on any academic test. However, if our sample is selected for intelligence (as for example at a good university where all students have IQs beyond 120) then the correlation is bound to fall. Everyone has sufficient ability to do the work and thus other factors, such as special abilities, interests and perseverance, become important. This point becomes absolutely clear if we were to imagine the impossible case where every student had the same IQ. There its relationship with any other variable would be 0.

The unreliability of measures is the other source of reduction of correlations. The reliability of a test is essentially its correlation with itself. Ideally this should be unity but in practice it falls far short of this. The reliability is the upper limit of the possible correlations with a test. Thus if both measures are unreliable correlations are necessarily reduced. Fortunately most good intelligence tests have high reliabilities but in other fields, such as personality, this is not so, and great care has to be taken in interpreting any results.

Factor analysis

Factor analysis is a statistical method in which variations in scores on a number of variables are expressed in a smaller number of dimensions or constructs. These are the factors. In almost all psychological, psychometric studies factor analysis is applied to the correlations between variables. The factor analysis shows the correlations of each of the variables with these constructs or dimensions. Factors are defined by these correlations, called factor loadings. An artificial example will clarify the point.

Suppose that intercorrelations had been obtained between all the subjects commonly studied at school. A three-factor solution would undoubtedly account for most of the intercorrelations. One factor would be general with loadings on all the subjects. There would be high loadings on subjects such as Latin, maths and physics and much smaller ones on physical education, woodwork and domestic studies. This would be identified from this pattern of correlations as *g*, or general ability. Complex, 'hard' subjects have the highest loadings on this intelligence factor. A second factor would load on English, French, German, history, geography (but less) and on all subjects where language skills were important. This is the verbal ability factor. A third factor would emerge, which loaded on maths, physics, chemistry and statistics, and would be a factor of numerical reasoning. The identification of these factors springs from their loadings. What is a construct that correlates with scores on language tests? Verbal ability is a sound inference. In psychometric work these factors would be further studied experimentally in new research in order to validate the identification based upon their loadings.

This example of a factor analysis illustrates the powerful ability of the technique to simplify complex data. If we were to examine the correlations between all the variables there would be far too much information for the mind to take in. However, three factors can be grasped. The scores on these three factors would be virtually as good an indication of the ability of the individuals who had taken the tests as the original scores on all the variables.

Definition of a factor

The definition of a factor adopted in this book is that of Royce (1963) and is one that is used, in practice, by the majority of psychometrists. In fact it is the definition which I used above in my discussion of factor analysis. A factor is a construct operationally defined by its factor loadings.

Factor loadings

These are the correlations of the variables with the factor. In my school example the verbal factor was identified by the fact that it had loadings on tests that clearly required verbal abilities, and, equally importantly, had no loadings on tests that did not require such ability.

It is useful to consider these two definitions together, since it is hardly possible to talk of factors apart from their loadings. The first point to notice concerning this definition of factors is that their status as constructs is very different from that of the same terms in everyday language. To take up the school example again, many people, entirely ignorant of factor analysis, might suppose that verbal ability was important in the learning of a language. However, without factor analysis there is no evidence, except from common sense, that such a construct is anything more than an abstraction based upon the fact that some people learn languages more quickly than others. Furthermore there is bound to be disagreement concerning the definition of so subjective a construct. The factor analytic construct is defined by its loadings with numerical precision. Furthermore the existence of the factor guarantees that it is a useful construct that can account for the variance in the test scores.

Identification of factors

Although a factor is defined by its loadings such a definition is not sufficient in itself. This is because in some cases the mix of variables on the factor is such that one cannot be certain from the loadings alone how the factor should be identified. A more important reason for requiring further evidence is the argument, used by Heim (1975) and others who do not favour factor analysis, that factors are simply mathematical abstractions derived from correlations and that they bear no necessary relationship to anything in the real world, beyond the correlation matrix.