Chapter 8

INTELLIGENCE: THEORIES AND ISSUES

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Of all the areas of Psychology, intelligence is probably the most controversial. At the same time, it is also one of the oldest areas of the discipline, dating back to the 1880's with the work of Francis Galton on individual differences in sensory functioning. It is impossible to capture in a single chapter the immense body of theorising and research that has been devoted to the topic of intelligence. The aims of this chapter are considerably more modest: a) to give a brief historical overview of the area; b) to show how developments in the field are tied to the methodologies used to study intelligence; c) to describe current approaches to intelligence; and d) to introduce the reader to some of the main controversies in the area. This chapter will trace the developments of the construct, from Spearman's (1904) early conceptions of intelligence as mental energy to the much broader conceptions of modern day theorists. The chapter will also deal with the wider social context and the implications of our understanding of intelligence for society in general. As will be seen, it is not an easy construct to understand but it cannot be ignored because, along with personality, it is one of the most fundamental aspects of the human psyche.

Why Is Intelligence Such an Important Topic?

What sets the area of mental abilities apart is the perceived importance of these abilities in our daily lives. We accept that we are physically stronger or weaker than other people, but few of us care much that someone is stronger or weaker than we are. It doesn't make a great deal of difference to our lives. In the cognitive domain, however, we are constantly compared with others, we compete with each other at a cognitive level for the best courses at universities, the best jobs, and for the best partners in life. Gottfredson (1997) stated "…no other ability has been shown to have such generality or pervasiveness of effect as does intelligence" (p.6).

The ancient Greeks were aware of the concept of intelligence, the Chinese before them, and every culture since. Former Australian Prime Minister, Bob Hawke, used the term "clever country" to describe his vision of what kind of a nation he thought Australia should become. Newspapers, particularly the Sunday variety, often contain stories on some new wonder drug or some new training programme that can increase intelligence. The popular media is also fascinated by displays of intelligence: children who can perform amazing computational feats, quiz show marvels who can recall facts with astonishing speed, musical and artistic prodigies, and so on. However, if we are to heed the advice of our former leader, and aspire to be clever, we must begin with some understanding of what the term means. As we shall see, it tends to mean different things to different people.

Definitions of Intelligence

A satisfactory definition of intelligence has always proved elusive. A symposium of 17 experts in the field convened by the editor of the *Journal of Educational Psychology* in 1921 to discuss the meaning of intelligence came up with almost as many interpretations as there were experts present. Intelligence was variously described as "ability to learn" (Buckingham), as "the power of good responses from the point of view of truth or fact" (Thorndike), as "the ability to carry on abstract thinking" (Terman), as "the ability of the individual to adapt himself adequately to relatively new situations in life" (Pintner), as "involving two factors - the capacity for knowledge and the knowledge possessed" (Henmon), as "the capacity to acquire capacity" (Woodrow).

Carroll (1993), to whom the author is indebted for the above information, reported that a similar symposium was convened in 1986 by Sternberg and Detterman to update the findings of the 1921 symposium. Twenty-five experts at the 1986 symposium came up with almost as many views of intelligence. Intelligence was described as "a quality of adapative behaviour" (Anastasi), as "the end product of development in the cognitive-psychological domain", as "a societal concept that operates in several domains - academic, technical, social, and practical" (Carroll), as "error-free transmission of information through the cortex" (Eysenck), as "acquired proficiency" (Glaser), as "mental self-government" (Sternberg). Carroll (1993) reported that "the symposium did not produce any definitive definition of intelligence, nor was it expected to" (p. 36). This second symposium did, however, reflect some of the newer views of intelligence, such as metacognition (the ability to understand and control oneself), emphasising the fact that views of intelligence are changing over time.

In a recent review of human abilities, Sternberg and Kaufman (1988) threw the definitional problem wide open by reminding us that non-Western views of intelligence may differ quite markedly from those expressed above. The Western emphasis on speed (see later sections of this chapter), for example, is not shared by many cultures. Questions of definition become more difficult if one moves beyond the human sphere to consider whether or not intelligence is something that is shared with other species. The Greek philosopher Anaxagoras believed that all animals have intelligence, but humans were superior. Aristotle arranged the animal species in a hierarchy with man at the top. During the middle ages, Christian theology dominated thinking about such issues and the doctrine of special creation replaced the view of continuity in nature. The doctrine separated animals and humans by the presence of a soul in humans and by the human's capability for reason. The emergence of Darwin's theory of evolution in the late 19^{th} Century brought humans and animals together again on the same continuum. Darwin stated that the difference between the mind of a human and that of the highest animal was one of degree and not of kind. Two books bearing the title "Animal Intelligence" were published in the 19^{th} Century.

Contemporary views of intelligence in animals are more flexible. Herman and Pack (1994) reported on a number of research programmes studying the behaviour of pigeons, chimpanzees, rats, and dolphins. These programmes have demonstrated that dolphins can remember lists of sounds and show the same primary and recency effects as humans; pigeons can reliably place classes of objects in different perceptual categories; vervet monkeys use different vocalisations to refer to four different types of predators; dolphins can learn to understand sequences of human commands where understanding depends on the meaning of words and word order; a variety of different species can learn various counting tasks; wild chimpanzees appear to actually tutor their young in the art of nutcracking; different animal species can show "deceitful" behaviour; e.g., feigning injury to lure predators away from young.

The list goes on. How these various displays of apparently intelligent behaviour relate to the concept of intelligence is still problematical. To keep matters as uncomplicated as possible, this chapter will leave the definition of intelligence open and deal only with research relating to human intelligence. The origins of that research date back to the end of the 1800's.

Theories of intelligence

There are too many theories of intelligence to cover in a single chapter but some have been much more influential than others. These will be summarised in the following section.

Spearman's one-factor theory

The figure normally associated with the origins of the concept of intelligence is Francis Galton who, in the late 1800's, was using tests of sensory discrimination to measure intellectual ability, often judged at that time by teachers' ratings. The idea of using such simple tests would strike many people today as being naive but Galton was anything but naïve. Howard (1991) reports that at the age of four he wrote this letter to his sister:

> My Dear Adele,
> I am four years old and can read any English book. I can say all the Latin substantives and adjectives and active verbs besides 52 lines of Latin poetry. I can cast up any sum in addition and can multiply by 2, 3, 4, 5, 6, 7, 8, 9, 10, 11. I can also say the pence table. I read French a little and I know the clock.

Quite clearly, Galton did not suffer from a lack of intelligence himself! The logic of using sensory measures was sound enough. All information comes to use via the senses and the quality of our mental processes will depend to some extent on the quality of the sensory input. It followed, therefore, that those with better sensory discrimination processes could well have better quality mental processes as well. Logic notwithstanding, Galton's simple tests did not discriminate between so-called "intelligent" and "non-intelligent" people. Nevertheless, his views were influential and most of his contemporaries followed his lead in exploring intelligence through basic sensory functions. Charles Spearman, one of the leading figures in the history of intelligence, began his illustrious career using these same sensory discrimination tests.

The first real breakthrough in the field of intelligence stemmed from a practical problem in the French education system. Following the introduction of universal education in this country, there was a need to identify students who had learning difficulties. Alfred Binet was given the task of developing psychological and physical diagnostic procedures for determining retardation and he took the unusual step of developing a thirty-problem test that measured several abilities related to intellect, such as judgement and reasoning. The break from measures of sensory ability was important because, unlike the earlier sensory tests, scores on Binet's test did correspond with other ratings of intelligence. The popularity of Binet's tests - they were soon used in other countries as well - proved to be a much-needed stimulus for research on the nature of intelligence itself. In one of those accidents of history, about the time that Binet published his test (1904), one of the major figures in the field of intelligence, Charles Spearman, began publishing articles on his theory of intelligence. As Brody (1992) put it, "Spearman provided a theory and Binet provided a test" (p. 8).

Spearman was an English engineer and army officer who became interested in psychology late in life. He proposed a theory of intelligence that became known as the two-factor theory (Spearman 1904, 1927). In keeping with his engineering background, Spearman saw intelligence as comprising a central pool of energy that was required for all cognitive tasks. This was the first of his factors, a general factor that he labelled 'g'. In addition to the general factor, each task has something unique to itself, a specific factor. Spearman likened the second of his factors to engines, with an engine for every task. Thus, when a person attempts a mathematical problem, it is 'g' that provides the energy for the operation and a specific mathematical engine that is responsible for the execution of the task. People differ in the amount they have of each and it is these differences that explain the variation we observe between individuals on cognitive tasks.

Spearman's two-factor theory of intelligence has been extremely influential because he developed techniques for measuring the extent to which a test measured 'g' - its "loading" or "saturation". Some tests measured it very well, others hardly at all. Spearman knew, for example, that 'g' could not be measured very well by tests of sensory discrimination, as Galton had tried to do. It could be measured by tests of comprehension, memory, and reasoning. Spearman recognised that the best predictors of academic ability were tests that required the "eduction of relations and correlates" which he defined as follows:

> The eduction of relations … when a person has in mind any two or more ideas … he has more or less power to bring to mind any relations that sensibly hold between them.
> It is instanced whenever a person becomes aware, say that beer tastes something like weak quinine … or that the proposition " all A is B' proves the proposition "Some A is B".

> The eduction of correlates … when a person has in mind any idea together with a relation, he has more or less power to bring up into mind the correlative idea.
> For example, let anyone hear a musical note and try to imagine the note a fifth higher …(Spearman, 1927, pp. 165-166, cited in Brody, 1992).

The problem was that Spearman was describing processes that could not be observed directly. What he could observe directly were the scores that people were obtaining on tests that he was developing to measure 'g'. He could also observe, as others had done before him, whether there was any correspondence between scores on tests of 'g' and academic achievement. One of Spearman's major criticisms of earlier work on intelligence was that it did not use quantitative indices of the degree of relationship between different measures. Spearman was the first to actually use correlations as the raw data upon which a theory of intelligence is based. For those who may be unfamiliar with the concept of correlation, a brief description follows.

A correlation coefficient can take values from 1.00 to -100. A correlation of 1.00 between any two tests means that they are perfectly related. If you knew how well a person performed on one test, you would know how well they performed on the other. For example, if a child topped the class on the first test, a correlation of 1.00 necessarily implies that the child tops the class on the other test. A correlation of -1.00 also indicates a perfect relationship but this time in an inverse manner. Thus, if a child came top of the class on one test that same child would necessarily be at the bottom of the class on the other test. The actual index of correlation is usually somewhere between these perfect extremes. The closer the index is to 1.00 or -1.00, the stronger the relationship between the variables. The closer to zero, the weaker the relationship, until at 0.0 there is no relationship at all between the variables.

For Spearman, the correlations among the tests he used were the data his theories had to explain. One thing struck Spearman quite forcibly: there were no inverse correlations among his cognitive measures. He used the term "positive manifold" to describe the tendency for all cognitive tasks to be positively correlated. To observe that two tests are positively correlated is one thing, to explain it is another. One explanation for the observation of a correlation is that performance on the two tests is driven by the same underlying ability. In fact, this is one of the foundations of theory building in the field of individual differences, of which intelligence forms a part. Spearman's observation that all cognitive tests are positively correlated led him to claim that despite obvious differences in the content of the tests (e.g., some measuring word knowledge, others spatial ability), they all rely to some extent upon 'g'. Thus, to a very large extent, Spearman's two-factor theory was driven by his attempt to explain the phenomenon of positive manifold. He did so by stressing the importance of a dominant single factor. As I mentioned earlier, the specific factors were added to the theory to account for differences due to unique operations called for by each test.

It is important to recognise the empirical basis for Spearman's theory. There is no doubting the fact that cognitive tests do tend to be positively correlated. Where subsequent theorists have differed from Spearman is in their accounts of what it is that all tests have in common and how much emphasis should be placed on the general factor. Spearman's description of 'g' as mental energy was disputed by one of his contemporaries, Godfrey Thompson, who argued that there was a large set of independent bonds or units in the mind. Any test of ability samples some of these bonds. The correlations that Spearman explained in terms of sharing a central energy source were explained by Thompson as tasks sharing the same bonds. Thus, if two tests sample a large number of bonds, by the laws of chance some of these will be the same and it is the sharing that accounts for the observed correlations. Thompson explained the obvious individual differences in intelligence by claiming that each individual possessed only a subset of the universe of bonds and that individuals differed in the number of bonds or units of intelligence they possessed (Brody, 1992).

Other accounts of the tendency for all cognitive tasks to be positively correlated have arisen over the years. For the most part, they have followed Spearman's lead in looking for a single entity that is shared by all cognitive tasks. Hunt (1980), for example, likened the concept of attention to that of 'g'. As Hunt knew, however, the comparison did not help to clarify the nature of intelligence because attention is just as elusive a concept as intelligence. An alternative interpretation of 'g' is that it reflects the ability of the individual to organise processing strategies to face new kinds of mental problems. This account of intelligence is reflected in the work of information processing theorists who stress the importance of metacognition as a component of intelligence (e.g., Sternberg, 1979). What follows from metacognition are planfulness, self-monitoring, and inventiveness, each of which can be thought of as hallmarks of intelligent behaviour.

In a similar vein, it has been suggested that the primary difference between persons of normal intelligence and the mentally retarded lies in the degree to which people are able to develop and use information processing strategies (Belmont, Buttefield, & Ferretti, 1982). They postulated a process called "Executive Functioning" which monitors and controls these strategies. Detterman (1982) pointed out that Executive Functioning is analogous to the general intelligence factor since its effects should be evident in every sort of mental test or cognitive task.

More recent research on intelligence has also been used to support Spearman's notion of a central factor of intelligence. Brody (1992) reported on research that relates individual differences in intelligence to measures of the overall metabolism of the brain. Interestingly, these studies still rely on correlational data. The research shows a high negative correlation between a measure of energy expenditure of the brain and scores on a test of abstract reasoning ability. In other words, more intelligent people do not expend as much energy on the task. "These findings may be viewed as providing support for a contemporary version of Spearman's theory of mental energy" (Brody, 1992, p. 12). A number of modern researchers have gone one step further than this and are searching for the basic processes that constitute 'g'.

The debate between Spearman and Thompson is characteristic of other debates that have occurred in the history of this branch of the discipline of psychology. The problem with correlational data is that different interpretations are always possible and both Spearman's and Thompson's theories were able to account for the data generated by early studies of intelligence. Before long, however, it became evident that Spearman's theory of a single factor of intelligence that accounted for all observed correlations among tests could not be correct. The need for mass testing of recruits during the First World War had given the testing movement a lot of impetus and many new tests had been developed. It soon became increasingly obvious that groups of tests tended to have more in common with each other than their 'g' loadings suggested they would. A set of spatial tests, for example, which might not be very good measures of 'g', tended to be highly correlated with each other. The same could be said for groups of verbal tests, numerical tests, and so on. As the data accumulated, it became clear that Spearman's two-factor theory of intelligence could not account for the data. The only possible explanation was that tests could be correlated for reasons other than their dependence on 'g'.

Thurstone's theory of primary mental abilities

Spearman was aware of the evidence accumulating against his two-factor theory but he continued to emphasise the importance of the general factor. The real challenge to his theory came in the person of U.S. psychologist, Thurstone, who used his own versions of the new technique of factor analysis to demonstrate that there was not one underlying ability but a number of independent abilities. In order to understand the basis for his challenge, a brief introduction to factor analysis is necessary.

Mention was made earlier of the fact that correlations are the data upon which early theories of intelligence were based. When there are many tests in a study, however, there are also very many correlations. A study that includes 10 intelligence tests will generate 45 inter-test correlations. Many studies of intelligence contain far more than 10 tests. To overcome the problem of trying to analyse so many correlations simulaneously, Thurstone developed a technique known as multiple factor analysis (MFA). MFA is a mathematical tool that detects patterns of correlations among the tests in the study. Most textbooks describe factor analysis as a technique that is mainly used to reduce a large set of variables to a smaller underlying set of dimensions. One of the requirements of a successful factor analysis is that the underlying dimensions explain most of the intercorrelations among the input variables. The details of how it does this need not concern us here but it is important to have some understanding of how factor analysis works. Consider the following example.

Here are some data that I collected many years ago on three measures of reasoning ability (R1 to R3 in Table 1), three measures of verbal ability (V1 to V3), and three measures of spatial ability (S1 to S3). The means, standard deviations, and correlations are presented in Table 8.1.

Table 8. 1
Descriptive Statistics and Correlations Among Cognitive Variables (N = 126)

Tests	M	SD	R1	R2	R3	V1	V2	V3	S1	S2
R1		3.01	1.00							
R2	9.02	3.76	.73	1.00						
R3	11.34	3.68	.58	.51	1.00					
V1	5.33	1.68	.35	.31	.27	1.00				
V2	10.22	4.18	.36	.39	.34	.56	1.00			
V3	10.51	4.08	.28	.22	.39	.51	.54	1.00		
S1	6.63	2.89	.30	.24	.12	.10	.32	.21	1.00	
S2	11.37	3.68	.26	.32	.16	.22	.30	.19	.50	1.00
S3	14.19	3.75	.36	.37	.20	.16	.39	.27	.54	.62

To those not familiar with statistics, Table 1 contains the names of the nine tests in the first row and in the first column. The means and standard deviations of the tests are shown in columns two and three. The remainder of the matrix is a correlation matrix, showing the type of data that formed the basis for much of the research on the nature of intelligence. Boxes have been drawn around the correlations among each of the three subsets of tests so that they will stand out more clearly.

If you examine the correlations among all of the tests, one feature is immediately apparent: they are all positively correlated. These positive correlations illustrate the phenomenon that Spearman labelled *positive manifold*. However, if you look closely within each box you can see that the reasoning tests are more highly correlated among themselves than they are with the other tests in the battery. The same is true of the verbal and spatial tests, suggesting that there must be factors other than 'g' that cause tests to be correlated. In the present instance, it looks very much as though the data are suggesting that all the tests have something in common because they are all correlated. In addition, the data suggest that reasoning tests have something else in common amongst themselves that helps to explain their higher intercorrelations. The same is true for the verbal and spatial tests.

It was data sets like this that prompted Thurstone to develop his model of separate mental abilities. Using his own version of MFA, Thurstone analysed correlations obtained from large batteries of tests and concluded that there was not a single factor of intelligence but a set of primary mental abilities. With the dataset shown in Table 8.1 (Fogarty, 1984), it is possible to illustrate how he reached this conclusion. Using a modern factor analysis program on a laptop computer, the output shown in Table 8.2 was obtained.

Factor analysis is essentially a data reduction technique: it is designed to find an underlying set of factors that can explain performance on a set of observed variables. In this case, the observed variables are the nine tests administered to 126 people. If Spearman was correct, only one underlying factor ('g') would be needed to explain the correlations among the nine tests. If Thurstone was correct, a number of factors would be needed to explain the correlations. We can see from Table 8.2, that the output from factor analysis suggests that three factors are needed to explain performance on these tests and the correlations among them.

Table 8.2

Factor Analysis of Reasoning, Verbal, and Spatial Tests Using Varimax Rotation

		Factors	
Tests	1	2	3
R1	**.878**	.210	.177
R2	**.736**	.258	.179
R3	**.586**	.006	.301
V1	.233	.001	**.685**
V2	.211	.295	**.699**
V3	.145	.146	**.688**
S1	.140	**.637**	.111
S2	.112	**.715**	.140
S3	.185	**.802**	.154

The tests themselves are listed in the first column. The numbers in the next three columns indicate the extent to which a particular test depends on each of the three factors. Thus, the first reasoning test (R1), depends very much on Factor 1 because it has a high loading of .878 on this factor. It has low loadings on Factors 2 and 3, so does not depend very much on these two factors. We need to look at what other tests are loading on this factor to suggest what it might represent. Tests R2 and R3 are the only other ones that have high loadings on Factor 1, so we can call it a reasoning factor. Test R1 was actually a Number Series test, R2 a Letter Series test, and R3 a test called Sets. All three are known to measure reasoning ability, so it is not surprising to us that they group together in a factor analysis.

The last three variables (S1, S2, and S3) were all different kinds of spatial test. We can see that performance on these three tests depends very much on individual differences on Factor 2, and very little on the other two factors. We can feel quite safe declaring that Factor 2 represents spatial ability. Test V1 was a Spelling test, V2 a Scrambled Words test, and V3 a Hidden Words test. All three have high loadings on Factor 3 and low loadings on Factors 1 and 2, so we can say that performance on all three of these tests is driven by the same underlying factor. Because it is quite obvious what the three tests have in common, we can also suggest that Factor 3 represents verbal ability.

Set out in this way, the results of a factor analysis might appear trivial and uninformative. Select three tests of reasoning ability, three tests of verbal ability, and three tests of spatial ability and then subject the resulting intercorrelation matrix to factor analysis and one should hardly be surprised that the analysis indentifies three underlying factors corresponding to the ones used to select the tests in the first place. True enough, but turn the clock back to the late 1920's and early 1930's when terms such as "verbal ability" had no empirical basis and it is possible to see what a powerful tool factor analysis was to researchers in this field. By constructing tests that used different content and different processes, forming correlation matrices among the tests, and then subjecting the matrices to factor analyses, theorists were able to gain an impression of how many underlying factors were needed to account for variations in performance on cognitive tasks.

Thurstone placed great reliance on the techniques of MFA to refine his model of intelligence. From the data collected in studies involving a large number and variety of cognitive tests (56 in his first study), Thurstone concluded that intelligence was made up of seven independent primary mental abilities which were labelled S (Space), P (Perceptual Speed), N (Number Facility), V (Verbal Relations), W (Word Fluency), M (Memory), and I (Induction - i.e., reasoning). The number of abilities is not actually crucial to Thurstone's theory. It really does not matter if the true number is more or less than seven, what was important in Thurstone's early formulation of his Primary Mental Abilities (PMA) theory is that the abilities were described as independent, implying that you could be strong in one ability area and very weak in another. Not surprisingly, Spearman hotly disputed this point of view. Spearman had certainly realised that it was possible to identify factors other than 'g' but it was a long step from this position to one in which 'g' was ignored completely and abilities were said to be numerous and independent.

As has been the case so often in this field of psychology, the reason for the differences between these two contrasting views of intelligence had its roots in the methodology employed. Spearman used a technique of factor analysis that highlighted the importance of what was common to all tests, whereas Thurstone used a technique that maximised the chances of tests arranging themselves into independent groups. The three factors shown in Table 8.2 were obtained by a technique known in factor analysis as "orthogonal rotation". The mechanics of this technique need not concern us here but we can note that the factors that come out of such an analysis are bound to be uncorrelated. A different technique of rotation allows factors to be correlated. This technique is recommended by many researchers because it does not impose constraints on the factors: they can be uncorrelated or correlated.

In order to see the effect that different techniques of factor analysis can have, the data shown in Table 8.1 were reanalysed, this time allowing the factors to be correlated. The resulting factor analytic solution was much the same as that shown in Table 8.1. If anything, this second solution was even easier to interpret than the first. The important difference between the two solutions is that the second solution produced a factor intercorrelation matrix showing that the correlation between Factor 1 and Factor 2 was .395, between Factor 1 and Factor 3 the correlation was .512, and between Factors 2 and 3, the correlation was .354. This was the important fact that Thurstone had overlooked in this early work: it is possible to factor analyse a correlation matrix so that tests form groups that measure primary mental abilities, rather than a single general factor of intelligence, but these primary mental abilities are themselves correlated. The proponents of the single factor theory of intelligence were quick to claim that the cause of the correlation among these abilities was 'g'. The arrangement implied by this suggestion is shown in Figure 8.1.

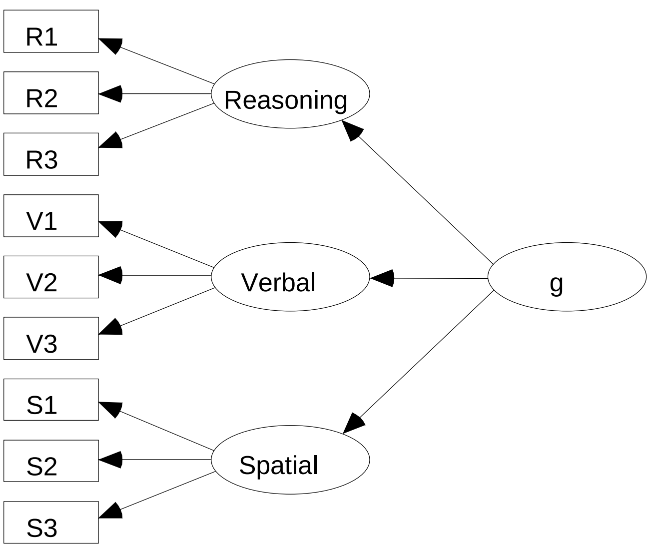

Figure 8.1. Depiction of relationships between tests, primary factors, and a general factor

Figure 8.1 shows that performance on tests used by Fogarty (1984) is driven by individual differences on the underlying reasoning, verbal, and spatial abilities. Performance on these abilities is in turn driven by individual differences in 'g'. Quite obviously, models of this type can be extended to include a larger number of tests and primary abilities. Such models represent a compromise between the positions of Spearman and Thurstone. They indicate that it is possible to have both primary mental abilities and a general factor of intelligence. The exercise that we have just completed with a subset of the author's own data was a re-enactment of analyses that were being conducted by a number of psychologists in the late 1930's and early 1940's. Eysenck (1939) re-analysed Thurstone's data using factor analytic techniques that did allow the 'g' factor to emerge. He found strong evidence for both a 'g' factor and for the same primary mental abilities that Thurstone had found. Cattell (1941) indicated that Spearman's theory and Thurstone's theory might be reconciled by postulating the existence of a hierarchical structure of ability. A number of very influential hierarchical models emerged in the 1940s, 50s, and 60s.

Hierarchical Models of Intelligence

The first well-acknowledged hierarchical model of intelligence was proposed by Phillip E. Vernon, a colleague of Spearman's. Vernon (1950) described a structure which placed 'g' at the top of an inverted tree-like figure. Immediately below 'g' were two other broad abilities, v:ed (verbal-educational) and k:m (spatial-mechanical-practical). Branching out from each of these were narrower group factors. For example, verbal ability was viewed as a narrow group factor located under the v:ed broad group factor and spatial ability was a narrow group factor under the k:m group. More specific abilities were located at a lower level still. Although, his model allowed various kinds of group factors, some broader than others, Vernon still felt that 'g' was the major determinant of individual differences in performance on cognitive tasks.

At about the same time that Vernon was developing his hierarchical theory of intelligence, another major figure emerged who was to initiate the work that led to what is now widely regarded as the dominant model of intelligence in the world today. Raymond Cattell was a student of Spearman's who moved to the U.S. and commenced work on both factor analysis and theories of intelligence. Like Vernon, Cattell believed that there was more than one higher-order factor. His view was that there were two kinds of intelligences: "fluid" (General Fluid: Gf) and "crystallised" (General Crystallised: Gc). Fluid intelligence was measured by tests that were assumed to measure the biological capacity of the individual to acquire knowledge. Reasoning processes were an important part of this ability. Crystallised intelligence, was defined by tests that were assumed to measure the influence of schooling and acculturation. Tests of general knowledge and vocabulary measure Gc. Thus, in a sense, crystallised intelligence represents the store of an individual's knowledge and skills whereas Gf represents the processes that helped the individual to acquire these knowledge and skills. The model proposed by Cattell bore some similarities to the model put forward by Donald Hebb (1949), who suggested that there are three kinds of intelligence: Intelligence A, that which we are born with, representing our innate potential; Intelligence B, representing the functioning of the brain as a result of the development that has occurred; and Intelligence C, representing measured intelligence. The first two of these are similar to Cattell's Fluid and Crystallised intelligences.

It was not until 1963 that Cattell gave a more complete account of his theory. In doing so, he was careful to look for more than just statistical evidence that the structure he proposed was valid. Gf was said to have a more biological basis than Gc. Indeed, it is defined by one author as "one's native, biologically endowed ability" (Howard, 1991, p.38). Thus, in the early stages of life, Gf helps to shape Gc. Later in life, as the brain began to deteriorate, Gf shows a decline. That is, it becomes harder for people to engage in the abstract reasoning processes that form the basis of some kinds of knowledge. Gc, on the other hand, is less affected by physical deterioration of the brain and certain types of knowledge can continue to develop virtually throughout one's lifespan.

Cattell was not the first to propose a distinction between two broad abilities of this type but his theory generated predictions, such as age-related decline in Gf, that were supported by empirical findings. His theory also attracted capable adherents, such as his student John Horn, who were able to take the model to new levels of development. Horn (1985) maintained the distinction between Gf and Gc but reinterpreted their meaning somewhat, especially Gf. Horn did not believe that Gf was a biological ability factor and he did not believe that there was a causal pathway leading from Gf to Gc, even early in life. Instead, both Gf and Gc are characterised by processes of reasoning, concept formation, and problem solving. The main difference is that Gf depends relatively little on the effects of formal education and cultural experiences (Stankov, Boyle, & Cattell, 1995).

The complexity of the Gf/Gc model has increased considerably since the first description by Cattell (1963). Figure 8.2 shows how the model looked to Horn (1985).

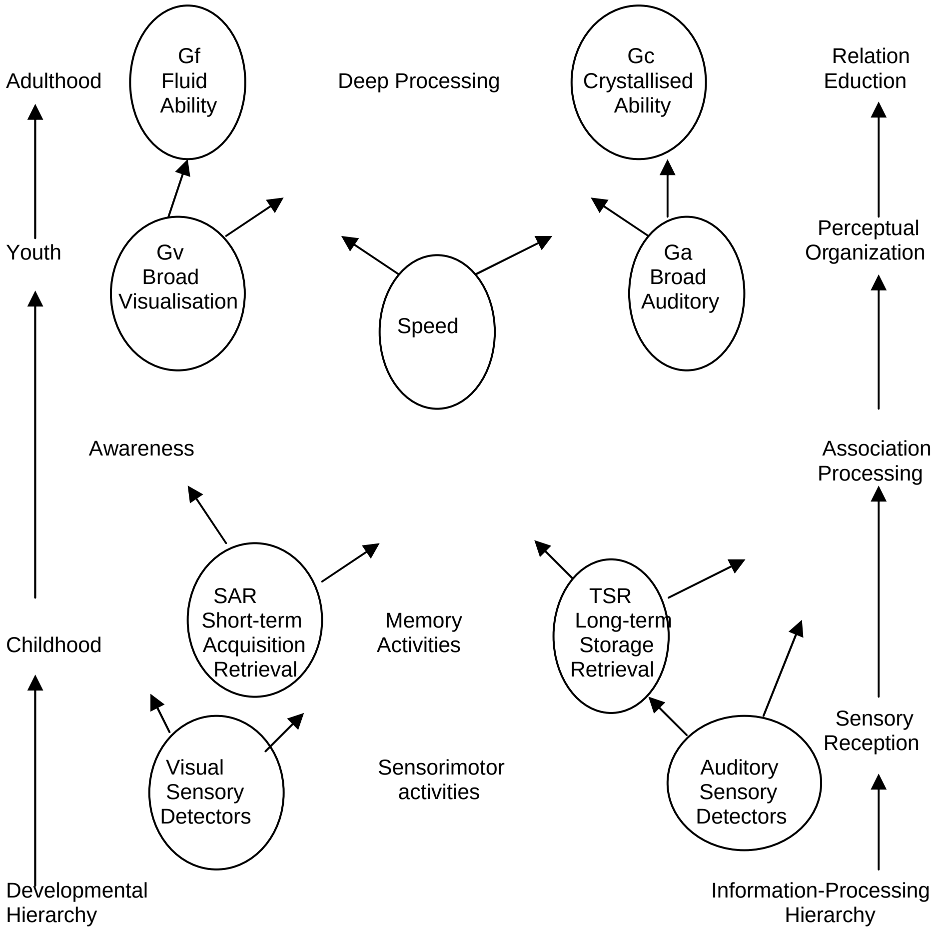

Figure 8.2. Representation of Horn's theory of intelligence (adapted from Horn, 1985)

Not model is not exactly as depicted by Horn, it has been simplified somewhat to suit our purposes, but captures the main features of Gf/Gc theory. A quick glance over this model shows how it seeks to explain much of what is already known about intelligence. To begin with, it is a hierarchical model. Notice, however, that there is no 'g' at the top of the hierarchy. Horn has a particular aversion to the notion of a general factor of intelligence, especially because of the way in which the concept of 'g' has been used to promote racist views. We will return to this controversy later in the chapter. As Carroll (1993) points out, however, if 'g' is ignored or denied, the theory does not really have an explanation for the correlation (about .50) that exists between Gf and Gc. Brody (1992) raised this same criticism.

The centre of Figure 8.2 contains circles enclosing the main second-order factors. Notice that there are 9 broad second-order factors in this model and that they are not shown in an inverted tree-like structure but rather in something that bears more resemblance to a chart. The left hand side of the chart shows a vertical line depicting the sequence of development from infancy to adulthood whilst the right hand side shows another vertical line representing the complexity of the processes at each level. Gf and Gc appear at the top of the hieararchy and they are characterised by what Horn calls "deep processing" operations. Spearman's eduction of relations and correlates exemplify the types of cognitive processes one would find at this level. At the next level down, we find the various perceptual organizational processes: visual abilities, auditory abilities, and processes related to speed of information processing. The placement of these second-order factors below Gf and Gc implies that they are less complex and that in a developmental sense, we master these abilities before we master the Gf and Gc abilities. Short term and long term memory functions are found about midway down the chart. The description of these functions as "Association processing" refers to the type of mental operation that is predominant at this stage of development, forming associations among facts, ideas, and so forth. At the very bottom level, are the sensory functions, the very sort of thing that Galton was assessing 100 years earlier in a vain attempt to measure intelligence. The model shows why these attempts were unsuccessful: the complex functions that we now know to be more central to intelligence are at the top of the hierarchy, whilst the sensory functions are at the bottom. Horn assumed that there would be little correlation among measures taken at the bottom of the hierarchy and substantial correlations among measures taken at the top. Galton did indeed find that sensory discrimination measures failed to correlate with teachers' ratings of intelligence. Binet, who sampled tasks from the top of the chart, found impressive correlations between his measures and measures of intelligence. The chart, however, also partially supports the logic of Galton's quest. Galton looked at sensory measures because he thought that good quality sensory input would lead to good quality mental processes. Horn's chart suggests that good quality input is a necessary but not sufficient condition for good quality mental processes. The input has to be processed and organized as it makes its way up the information processing hierarchy. Detection is just the first of the steps and there is no guarantee that someone who is good at this level will also be good at the other levels.

There are problems with Horn's model but it does accommodate many of the empirical findings noted in the literature. It also has the desirable characteristic of being an open model, one that invites further developments. The inclusion of perceptual organisation factors, for example, led to the recognition of the auditory organisation factor that appears in Figure 8.2 (Stankov & Horn, 1980). Stankov, a student of John Horn's who has worked for many years now at the University of Sydney, reasoned that if there can be spatial abilities, then there should also be auditory abilities. Obvious examples occur in the field of music but Stankov discovered a range of other tasks, some of them involving distortions of speech, that depend on this factor. Work of this kind has great importance in areas where auditory abilities are a matter of life and death (e.g., aircraft cockpits). Stankov and his colleages are now actively exploring the bases of individual differences in other sensory domains, notably touch. Indeed, the model has already been extended through the inclusion of a tactile-kinesthetic ability that has much in common with broad visualisation and fluid intelligence (Roberts, Stankov, Pallier, & Dolph, 1997). Roberts and his co-workers used tasks that required participants to identify objects by shape and texture, to perform a bead memory test blindfolded, to detect letters and figures traced on their fingers, and a variety of other tactile tasks. Their findings suggest other ways in which intelligence can be assessed, perhaps less culturally biased methods. Research has been active on other aspects of the Gf/Gc model as well. Attempts have been made to determine the status of other supposed factors such as attention (Stankov, 1983), the ability to divide one's attention (Fogarty & Stankov, 1982; Fogarty, 1987), the status of mental imagery ability (Burton, 1998), factors relating to cognitive style (Fogarty & Burton, 1996), and some very interesting recent work on cognitive speed factors (Roberts & Stankov, 1998). The results of this work will extend the model further. Carroll (1993) in his extraordinary review of factor analytic studies of human cognitive abilities had this to say about the Gf/Gc model:

The Cattell-Horn model, as summarised by Horn (1985, 1988), is a true hierarchical model covering all major domains of intellectual functioning. Numerous details remain to be filled in through further research, but among available models it appears to offer the most well-founded and reasonable approach to an acceptable theory of the structure of cognitive abilities. (p. 62).

Other models of intelligence

There are other models of intelligence that are also based on factor analysis or modifications of factor analysis. One of the most interesting of these is Guttman's radex theory (Guttman, 1954) in which he ordered ability tests in two ways, according to their complexity and according to their content. The first of these orderings is called a simplex, in which a proper ranking is possible. The second is called a circumplex, where proper ranking is not possible but where contents may still be displayed by ordering them in a circular way. It is possible to combine these two orderings in what Guttman called a radex where more complex tests are located towards the centre of a series of concentric circles representing increasing complexity, and where the various content areas are shown as sectors. A rather crude representation of a radex is shown in Figure 8.3. The concentric circles do not mark any clear borders but are shown to reinforce the impression of increasing complexity as one moves to the centre. Similarly, the four content areas shown are not meant to represent the sum total of all contents possible. Rather, they show four different types of content and illustrate the notion that tests employing a particular type of content will be found in the same sector. Four hypothetical tests, represented as black dots, are shown in the diagram. One test is located towards the centre of the radex. We know from its location at the centre that such a test would be a good measure of 'g'. Because it is in the figural sector, we can see that this imaginary test employs figural or pictorial items. There is another dot in the figural sector but in the outer circle. We can tell from its location that it would not be a good measure of general intelligence.

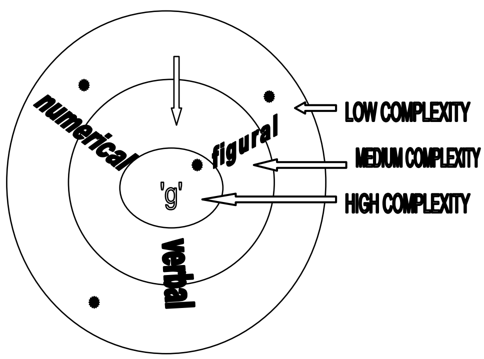

Figure 8.3. Represention of a Radex Model of Intelligence

Snow, Kyllonen, and Marshalek (1984) demonstrated that Guttman's model is compatible with the hierarchical model of intelligence derived from factor analysis. They were able to locate a large number of well-known measures of intelligence on a two-dimensional configuration, similar to that shown in Figure 8.3. These researchers believed that the radex models proposed by Guttman provide a generally more useful perspective on cognitive abilities and their relations than does factor analysis. They concluded that "The radex thus emerges as the most general theoretical model to date on both substantive and methodological grounds" (Snow et al., 1984, p.88).

Summary of the theories of intelligence based on factor analysis

Up to this point, the chapter has focussed primarily on the contributions of early workers in the field of intelligence. There are a number of reasons for this. The first is that this early work is still very relevant to our modern understanding of the concept of intelligence. Furthermore, it tends to concentrate on a narrow range of themes, it shows a reasonably clear development of the concept, and is thus easier to explain in a limited space. Another reason is that the practice of intelligence testing today is still very largely shaped by the work of these earlier researchers. Some of the most popular tests in use today are modelled on the theories developed by Binet, Spearman, Thurstone, Vernon, and Cattell. As we shall see in the concluding sections of this chapter, researchers have broken away from the relatively narrow approaches of the past. Some are now calling for the recognition of different intelligences, the sort that cannot be captured by standard psychometric tests. Developmental psychologists, such as Piaget, have long argued that we should spend more time looking at the processes by which all children come to think intelligently, rather than focussing on why they differ among themselves. There is also new interest in the neural and biological bases of intelligence, prompted by developments in medical technology that allow us better insight into neural processes. Researchers have argued that to base the concept of intelligence solely on the interpretation of patterns of correlation obtained from batteries of cognitive tests leads to a neglect of many important aspects of mental ability. Some of the alternative approaches are described in the next section.

Gardner's multiple intelligences

Gardner (1983) put forward some interesting ideas about the nature of intelligence in his book *Frames of Mind*. Gardner argued that our views of intelligence should be informed not only by work with "normal" children but also by studies of gifted children, of experts in various domains, of valued abilities in different cultures, and by individuals who have suffered types of brain damage. Gardner rejected the idea that there is a general ability that acts as a kind of "superability". Instead, there are several relatively independent intelligences which he defined as a set of problem solving skills in a given domain. In order for something to be considered an "intelligence", Gardner listed a set of eight criteria that had to be met. These are as follows:

1. Potential isolation by brain damage. In other words, if it can be demonstrated that a particular ability is affected by localised brain damage and other abilities are not affected, then this criterion is satisfied.
2. The existence of idiot savants, prodigies, and other exceptional individuals. Idiot savants are otherwise handicapped individuals who exhibit a high level of development in a particular ability. Gardner argued that if people can be exceptional in one area but only average or below average in others, then it constitutes evidence that the ability in question may be a separate intelligence.
3. An identifiable core operation or set of operations. For example, the ability to discriminate between tones is characteristic of musical ability.
4. A distinctive developmental history, leading to a stage of expertise.
5. An evolutionary history and evolutionary plausibility. Gardner felt that intelligences have evolved and that we should be able to trace their evolutionary history, or see evidence of it in other species. For example, rudimentary forms of linguistic intelligence can be seen in other species and the evolutionary value is clear.
6. Support from experimental psychological tasks. For example, if it is claimed that two intelligences are separate, then it should be possible to demonstrate in a laboratory setting that tasks drawn from each of the intelligences do not interfere with each other (c.f. Fogarty, 1987).
7. Support from psychometric findings. In other words, there should not be large correlations between tasks drawn from the different intelligences.
8. Susceptibility to encoding in a symbol system.

By looking for evidence of the conjunction of all these criteria, Gardner was able to arrive at a set of seven distinct intelligences. They are as follows:

1. Linguistic. The traditional verbal ability. Gardner was at pains to stress that although important for success, people could manage without being adept at linguistic intelligence. Einstein, unlike Galton, could not recite poetry and slabs of Latin at the age of four; indeed it is said that he did not speak his first words until four, and it is certainly recorded in many places that he preferred to think in images.
2. Spatial. Again, a traditional psychometric ability that refers to the ability to visualise spatial arrangements and to manipulate and transform them.
3. Logical-mathematical. The type of intelligence is tapped by many conventional intelligence tests (e.g., IQ tests). Gardner described this intelligence as involving both a love of dealing with ideas and the power to follow very long chains of mathematical reasoning. It is not hard to see why this intelligence has been highly valued in Western societies.
4. Musical. The power to understand the music of others, to reproduce it, and to compose one's own. Music has three essential elements: pitch, timbre, and rhythm. Those high in musical intelligence can integrate these well (Howard, 1991). Although many researchers dispute that music is a separate intelligence, there is no doubt that it does not correlate highly with traditional measures of intelligence, hence the need to create new measures to predict musical achievement (e.g., Fogarty, Buttsworth, & Gearing, 1996).
5. Interpersonal. Involves understanding and "getting on with" other people. The term "social intelligence" is often used to describe this same intelligence. John Horn developed measures of social intelligence as an indicator of crystallised intelligence. Gardner, on the other hand, believes that it is an intelligence in its own right.
6. Intrapersonal. This intelligence has to do with how well we understand ourselves, our motivations, moods, strengths and weaknesses. At first glance, this may seem a rather unimportant intelligence, but some interesting Australian work on self-knowledge will be discussed later in the chapter.
7. Bodily-kinesthetic. This pertains to body movements, sense of balance, hand-eye coordination, and so forth.

The critics of Gardner's theory point out that it is difficult to see how all these seven intelligences meet his eight criteria (e.g., Brody, 1992). They also point out that if subjectivity enters into the decision about what are intelligences and what are not, there may be a very large number of these indeed. The theories developed on the basis of factor analysis and related methods may be difficult for many to comprehend, but they were based on empirical data. Thus, the factors derived from the psychometric literature are well-established. Gardner's theory, on the other hand, appears to have both an empirical and a subjective basis. Gottfredson (1997) warned "Labelling other abilities and traits as other 'intelligences' creates only the appearance, not the reality, of multiple equally useful abilities" (p. 6). Despite these reservations, the theory has generated a lot of interest and stimulated research in relatively neglected areas.

Sternberg's triarchic theory

Robert Sternberg's (1985) triarchic theory proposed that there are three fundamental aspects of human intelligence - analytic, creative, and practical. Analytic intelligence is what is typically measured by intelligence tests. Problems testing this type of intelligence usually a) have a single correct answer, b) come with all the information needed to solve them, and c) have little intrinsic interest. Practical problems, in contrast, tend to a) require a definition of the problem, b) be poorly defined, c) have several solutions, d) require everyday experience, and e) require motivation and personal involvement. Sternberg was not the first to make a distinction between analytic and practical intelligence, Neisser (1976) had done so much earlier, but research supporting the distinction did not emerge until the 1980s and 1990s. Ceci and Liker (1986) in a study of expertise in betting on horse races, found that handicappers used quite complex interactive models with as many as seven variables. Despite the seemingly obvious reliance of this type of ability on mathematical skills, level of performance was not correlated with IQ scores. There are other examples of complex skills being displayed in the workplace by people who do not score well on IQ tests. One criticism of these examples, however, is that they involve highly learned skills. In separate writings, Sternberg has emphasised the importance of coping with novel (what he called "nonentrenched") situations as a hallmark of intelligence. Ackerman (1988) has shown that intelligence plays a smaller and smaller role as a task ceases to be novel and becomes more automatic. It is sometimes difficult to say whether people displaying high levels of skills in a workplace situation are displaying practical intelligence or highly overlearned skills. Motivation is also a major consideration.

Whilst there may be some question about the status of practical intelligence, there is no disputing the status of what Sternberg called "creative intelligence". The notion of creative ability has existed for a long time. Research has shown that creative people tend to a) be experts in their field, b) have the capacity to think differently about problems, and c) be motivated by intrinsic (e.g., satisfaction) rather than extrinsic (e.g., money) rewards. Anastasi and Urbina (1997) reported that correlations between tests of intelligence and creativity tend to be low, although an average or above average intelligence is necessary but not sufficient for creativity to emerge. Unfortunately, it is very difficult to measure creativity and Sternberg's recognition of creative intelligence in his model has not really taken us any closer to understanding its nature.

Piaget's theory

Most people today are familiar with the theories of cognitive development put forward by Swiss psychologist, Jean Piaget. As stated earlier, Piaget was not interested in individual differences in intelligence but in the means by which all children learn to act in an intelligent manner. His theory was constructed primarily on the basis of observational data. The four stages of cognitive development described in this theory give an insight into what he considered intelligence to be.

1. Sensori-motor. A stage lasting up to the age of two during which the child is capable of very limited cognitive operations, mostly sensory in nature.
2. Pre-operational. Lasting from two to seven years during which the child starts to develop a sense of concepts such as number and weight, but still only in a limited way. Everything is taken very literally.
3. Concrete operations. The child is no longer so dominated by the appearance of things and is capable of a range of operations but is still not capable of abstract thought.
4. Formal operations. From 11 years onward the child is increasingly capable of abstract thought. Piaget mentions the grasp of concepts such as probability as an indication that people have reached this stage. Many statistics lecturers would claim that some students never reach the formal operational stage!

It is interesting to compare this sequence with those shown on the left and right hand sides of Figure 8.2, which depicts Horn's version of the theory of fluid and crystallised intelligence. The two versions of the development of intelligence are not dissimilar. Both show a developmental sequence wherein humans begin by dealing with sensory data, move to a stage where they form associations, and then ultimately progress to abstract levels of thinking. However, it would be a mistake to think of Piaget's model purely in terms of this progression from sensory perception to abstract thought. His model is rather complex and incorporates an explanation of how we actually acquire information and develop knowledge structures. The driving force behind intellectual progression is the struggle to make sense of our experience. We do this by building schemas, mental models that represent our view of the world. Once a schema is formed it can be used to *assimilate* new information. If the information is incompatible with the schema, we may be forced to alter the schema itself and restore equilibrium through a process that Piaget labelled *accommodation*. This is how learning occurs. At the same time, children are acquiring an increasingly complex range of cognitive operations, to the point where as adults we are capable of thinking about thinking itself.

Piaget's views changed the way people thought about intelligence, especially the intelligence of children, and had a big impact on curriculum design in many countries. His account of intelligence certainly represented a different point of view to the one being espoused by the factor analysts, who were developing their theories on the basis of individual differences observed in performance on cognitive tests.

Biological approaches to intelligence

In recent years, one of the fastest growth areas in psychology has been the search for biological foundations for psychological constructs. Stankov, Boyle, and Cattell (1995) provided a succinct summary of these developments in the field of intelligence. A brief review follows.

1. Brain Size. There is no doubt that brain size is related to degree of intelligence across species, although not within species. Absolute brain size is not important but the ratio of brain size relative to body size does give a good indication of the intelligence of the species. A person living today has a brain almost four times as large as one of our human ancestors who lived more than three million years ago (Di Lalla & Patrick, 1994). In the process of evolution, the cortex became more and more convoluted. The human brain is three times

as large as that of a chimpanzee, yet has only 1.25 times as many neurons. The distinguishing characteristic of the human brain is the very large number of interneuronal connections, many of which have formed over the past 3 million years. The cause of this extraordinary change in our brain structure is undoubtedly related to increased tool use, increased complexity of social systems as humans ceased to be hunter-gatherers and started living in larger and larger communities, and increased dependence on written and spoken language. Individuals with more complex brain structures were more likely to survive and reproduce, passing on these physical characteristics to the next generation. Despite the obvious connection between brain size and intelligence across species, however, there is very little evidence suggesting that within-species variation can tell us much about intelligence, the correlations are too weak (Stankov et al., 1995). Even where the correlations are more robust (e.g., Willerman, Schultz, Rutledge, & Bigler, 1991), it is impossible to say what these correlations mean.

2. Biochemistry and intelligence. There have been reports of successful attempts to increase intelligence by nutritional means. Stankov cites one study that showed an increase of about 4 IQ points in children as a consequence of an intervention that assured a normal daily intake of vitamins and minerals. However, there is no reliable evidence that children already enjoying a normal intake of the same substances will show an increase in IQ (to use this term as a synonym for measured intelligence). Temporary boosts can be obtained by the use of stimulants, such as caffeine, but these substances will not have long-term effects.
3. Neural efficiency and intelligence. Brain imaging techniques now allow us to observe metabolic processes in the brain during the performance of cognitive tasks. It is early days yet for this kind of research but the evidence so far suggests that higher intelligence is associated with faster and more efficient neural activity (Stankov et al., 1995; Sternberg & Kaufman, 1998). That is, intelligent people don't have "more brains", they have "more efficient" brains. Eysenck (1967) was the first modern theorist to push this view strongly. Progress is likely to be slow in this research area because recording techniques are still somewhat unsuited to measuring things like speed of neural transmission and the imaging technique itself is very expensive.
4. Health, age, and intelligence. There is not much evidence of the effects of poor health on intelligence. Stankov and co-workers at the

University of Sydney have found that there is a definite decline in fluid intelligence abilities with aging but that "higher mental functions seem to be largely spared the effects of transitory physical illness" (Stankov et al., 1995, p.24).

Modern trends in the study of intelligence

One modern trend has already been mentioned, the tendency to search for biological correlates of intelligence. Two other trends are worth mentioning. The first has to do with a general opening up of the field of intelligence. Over the years, many abilities have been suggested but, for the most part, research has focussed on what has often been called analytical intelligence. In recent years, the field has expanded and researchers are now looking at the relationship between intelligence and personality (e.g., Stenberg & Ruzgis, 1994; Stankov et al., 1995). Stankov et al. (1995) concluded that both normal and abnormal personality traits can influence cognitive abilities but that the mechanism and the extent of its influence is unclear. Ackerman and Heggestad (1997) have thrown the net wider to include intelligence, personality, and interests. They found evidence that the three traits work in tandem with ability level and personality dispositions determining the probabilty of success in a particular task domain, and interests determining the motivation to attempt a task. Further research of this type will help to elucidate how a broad range of constructs, such as values, combine with intelligence, personality, and interests to determine behaviour.

A second encouraging trend in intelligence research has seen the continuing cross-fertilisation between the fields of cognitive psychology and individual differences. Hunt (1978, 1980) started this trend when he began to search for the basic processes involved in verbal ability. Following Hunt, cognitive psychologists began to use some of their experimental tasks, developed to measure very specific processes, as a way of shedding light on the factors identified by those working within the psychometric tradition. This has led to research in the area of cognitive speed and the use of very basic speeded tasks to measure intelligence. Researchers in South Australia (Vickers, & Smith, 1986; Nettlebeck, 1997) have developed a task called inspection time that reliably correlates with measures of intelligence. The IT task involves the discrimination of a very briefly presented stimulus and is said to measure the effective speed of intake of stimulus information. Deary and Stough (1996) have claimed this research programme as a success story in the reductionist approach to human intelligence. On a much broader level, but still inspired by cognitive theory, Stankov and Crawford (1997) have been working on the concept of self-confidence and studying its relationship with human abilities. They concluded that "There exists a separate self-confidence trait that is tapped by confidence ratings from diverse cognitive measures. This trait may be viewed either as an aspect of metacognition and therefore close to human abilities or as part of the interface between abilities and personality" (Stankov & Crawford, 1997, p. 11).

These research programmes are helping to clarify the nature of intelligence but the reality is that there are not a lot of people working within the psychometric tradition, either here in Australia or overseas. One reason for the relative lack of researchers is undoubtedly the complexity of the psychometric method for many aspiring students. Another reason is the controversy that has from time to time surrounded the area. This chapter will close with a brief consideration of these issues.

Issues and controversies in intelligence

Unfortunately, the field of intelligence is as well known for its controversies as for its contributions to understanding human behaviour. Some of the controversies have attracted widespread publicity. This section will touch on the main controversies and relate their origins to work discussed earlier in this chapter.

Improvement in Intelligence

The issue of whether intelligence test scores can be improved over the span of an individual's life is a complex one. At a general level, intelligence is like everything else: use it or lose it, as the popular saying goes. Given the right circumstances, obviously some improvement is possible, but it depends on what type of intelligence one is talking about. Crystallised intelligence can certainly go on improving, until late in life it seems. Fluid intelligence, on the other hand, appears to suffer a decline before one has reached middle age. Life habits (e.g., drug abuse) can accelerate the decline.

One of the most interesting findings to emerge in relation to changes in intelligence occurs at the population, rather than the individual, level. It has been observed in a large number of Western cultures that intelligence test scores have been rising steadily since they were first measured on a large scale in the 1930s. The effect is very powerful - at least 15 IQ points per generation for tests of fluid intelligence (Flynn, 1987). Our children are scoring much better than we did at the same age. Explanations are not easy to come by but suggestions include increased schooling, better nutrition, and a host of improved environmental factors.

The role of the general factor

Perhaps the most contentious issue in the history of research on intelligence has been the role of the general factor. Spearman and Thompson debated whether it existed and researchers since then have debated the importance that should be attached to it. Hierarchical models of intelligence showed that there was no necessary incompatibility between theories that stressed the general factor and theories that stressed primary mental abilities; it just depended where you looked in the hierarchy. Nevertheless, the question of the relative importance of each has always generated fierce debate. The strongest proponent of the importance of 'g' in recent times has been Arthur Jensen (1979, 1980). One of the strongest critics has been John Horn.

One reason so much heated debate has surrounded this question is that some of the proponents of a single-factor theory of intelligence have been associated with research that claims to demonstrate race differences in intelligence. As Stankov put it:

> Although it is not necessarily the case that the single 'g' factor position calls for a value laden view of group differences in intelligence, it just so happens that those holding a multiple intelligence view (Gardner, 1983; see also Horn & Noll, 1994) appear to be more sensitive in their discussion of racial issues. (Stankov, 1998, p. 55).

Stankov also feared what he saw as a tendency to "mindless reductionism" among some of those who hold the single factor view. In particular, he stressed that emphasising a single factor ignores a large body of evidence pointing to the existence of many factors at different levels of complexity. Such a narrow view overlooks the richness of human cognition.

The problem with attaching too much importance to speed, and hence to the brain, is that there is not a lot that we can do about brain structures. There is a danger that over-reliance on biological explanations of intelligence will encourage us to think of intelligence as something that is immutable. Furthermore, whilst speed and neural efficiency are undoubtedly important aspects of analytical intelligence, and worthy of continued research, it is doubtful that it will play such a leading role in other types of intelligence discussed in this chapter, such as those listed by Gardner.

Race differences in intelligence

Along with the issue of the importance of the general factor, questions of race differences in intelligence have always sparked a heated debate. Arthur Jensen and Hans Eysenck separately published extensive data showing that as a group black Americans scored about one standard deviation lower than white Americans on standard tests of intelligence (e.g., Jensen, 1985). That announcement in itself was unlikely to cause a great deal of controversy. Concern, yes, controversy, no. The controversial aspect of their work was the linking of this difference with genetic differences. If the difference has a genetic basis, some governments feel justified withdrawing funding support for programmes designed to improve learning opportunities for disadvantaged people. The 1994 publication by Hernstein and Murray of the extremely controversial book referred to as "The Bell Curve" saw an unprecedented level of discussion on this topic. The authors argued that unintelligent people are a drain on society and that society will eventually form itself into two classes: a privileged intelligent group and an increasingly underprivileged unintelligent group. Such sentiments are often expressed in society but Hernstein and Murray backed their claims with a detailed statistical analysis of research on group differences on IQ scores.

To understand the heat generated by this sort of discussion, it is helpful to return to the points made at the outset of the chapter about the importance of intelligence in our society and the consequences of scientists claiming that intelligence is genetically based. Not many scientists would deny that intelligence is partly determined by genetics but most would also acknowledge that learning experiences play a very important role. Unfortunately, although we have learned much about intelligence, we have not yet found a way to handle the controversies that are a byproduct of research in this area. As Rowe (1997) commented, whilst research on intelligence as a property of the mind (information processing, mental self-management) and the brain (speed of neural transmission, brain size, rate of brain metabolism) constitutes perhaps the most active frontier today in the study of intelligence, there has been no comparable sociology of intelligence to explain how the effects of this research reverberate through the social system.

The publication of Hernstein and Murray's book created such an uproar that the American Psychological Association set up a special Task Force under the leadership of Ulrich Neisser to report on factual issues relevant to the debate (Neisser et al., 1996). Some of the findings of the Task Force are summarised below and provide a fitting closing comment on many of the themes raised in this chapter.

1. The Task Force concluded that the genetic effects on measured intelligence are substantial but that the pathway by which genes produce their effects is still unknown.
2. The environment also exerts a substantial effect on the development of intelligence but, once again, we do not clearly understand what those environmental factors are or how they work.
3. The role of nutrition in intelligence is equally unclear. Although it is known that severe childhood malnutrition restricts cognitive development, there is no convincing evidence that dietary supplements in normal populations has any positive effect on intelligence.
4. Information-processing speed and psychometric intelligence are related, but we do not yet know how important speed should be to our understanding of the construct of intelligence.
5. There are differences between Blacks and Whites on tests of intelligence which do not appear to be due to any obvious biases in test construction and administration, nor to differences in socioeconomic status. At present, we do not know why these differences exist.
6. The Task Force also mentioned the range of other abilities not currently sampled by existing tests of intelligence. These abilities include creativity, wisdom, practical sense, social sensitivity, and perhaps others that we do not yet know about. Whilst this situation persists, our understanding of the construct of intelligence is limited.

If these conclusions seem a little weak - a series of confessions about what we do not know - surely that is appropriate. Despite the progress in our understanding of intelligence, we still have a long way to go. The Task Force summarised the situation very concisely in its concluding comment:

> *In a field where so many issues are unresolved and so many questions unanswered, the confident tone that has characterised most of the debate on these topics is clearly out of place. The study of intelligence does not need politicised assertions and recriminations; it needs self-restraint, reflection, and a great deal more research. The questions that remain are socially as well as*

> *scientifically important. There is no reason to think them unanswerable, but finding the answers will require a shared and sustained effort as well as the commitment of substantial scientific resources. Just such a commitment is what we strongly recommend.* (Neisser et al., 1996, p. 97)

ACTIVITIES AND REVIEW QUESTIONS

Discussion Questions

1. Think about your own definition of intelligence. Write it down and be prepared to defend it to others.
2. What is your view of the relative importance of a general factor of intelligence? Is it more useful to think of a single factor of intelligence that can explain much of our behaviour? Or to think of the many different factors of intelligence?
3. Are there intelligences not mentioned in this chapter (e.g., emotional intelligence) that should be included in Gardner's list? What other ones can you think of?
4. Do you think that the term "intelligence" is too culturally bound to be useful outside Western Society?
5. Can you think of examples of behaviour in other cultures that would be considered intelligent but not so in our society?
6. Is intelligence a uniquely human quality? Or confined to certain species? Or does it form a continuum throughout the animal kingdom?
7. If intelligence is defined as "adaptation to one's environment", are all species equally intelligent?
8. What reasons can you suggest for the large increase in IQ scores from generation to generation?

At the time of writing this chapter, there is a site on the Web that will allow you to complete a short (5 min) intelligence test. There is no guarantee that it will still be around when you read this chapter, but here it is: "http://www.brain.com".

Review Questions (Answer true or false to the following statements)

1. Experts are the only people who are able to agree what intelligence means?
2. The term 'g' was coined by Francis Galton?

3. Spearman and Thompson differed regarding the importance they attached to the general factor.
4. Thurstone proposed that there were seven primary mental abilities.
5. Thurstone proposed the first hierarchical model of intelligence.
6. Cattell claimed that fluid intelligence (Gf) was biologically linked?
7. Hebb's Intelligence B represented our innate potential.
8. The Gf/Gc model is a hierarchical model of intelligence.
9. Two tests that are correlated are said to rely upon at least one common ability.
10. Factor analysis is a technique that forms the basis of all theories of intelligence.
11. Positive manifold is a term that refers to the tendency for all cognitive tasks to be positively correlated.
12. General crystallised intelligence declines with age whereas general fluid intelligence stays the same or may even increase.
13. Guttman's radex model classifies tests in terms of complexity and content.
14. Gardner subscribed to the view that there is a general factor of intelligence.
15. One of the three basic intelligences represented in Sternberg's triarchic theory was called "emotional intelligence".
16. Piaget did not use correlational methods but was very interested in individual differences in intelligence.
17. Piaget's stage of formal operations marks the point at which a child reaches the level of abstract thought.
18. It is not possible to judge intelligence within species by measuring brain size.
19. Research has shown that dietary supplements will boost intelligence for most people.
20. Differences noted between races on measured intelligence can be attributed to genetic influences.
21. Our children are smarter than we are.

Answers to Review Questions

1. False. Whenever experts in the field have been assembled to address this question of definition (e.g., 1921, 1986), there have usually been as many definitions as experts.
2. False. Charles Spearman invented the term to refer to whatever it was that all tests had in common. It was a mathematical abstraction

to which he gave some meaning by referring to it as a central energy source.

3. False, they differed regarding their explanations for positive manifold, that is, the tendency for all cognitive tests to be positively correlated. Spearman thought that it was because all tests tapped a central energy source, Thompson felt that it was due to overlap in the bonds used for different tasks.
4. True, they were S (Space), P (Perceptual Speed), N (Number Facility), V (Verbal Relations), W (Word Fluency), M (Memory), and I (Induction - i.e., reasoning).
5. False, Thurstone's model involved uncorrelated factors, so there was no basis for any hierarchy.
6. True, although Horn later argued that both Gf and Gc were biologically linked.
7. False, Intelligence A represents this aspect of intelligence in Hebb's model. Intelligence B represents developed intelligence.
8. True, although it might not look like the classical inverted-tree structure typically seen in hierarchical arrangements. It is a hierarchical model because it has higher-order factors.
9. True, in psychometrics the existence of a correlation between two tests is usually interpreted as meaning that performance on both tests is driven by at least one common underlying factor.
10. False, it is a technique used by many theorists but Gardner, Piaget, and a number of others did not use it.
11. True. The observation of this phenomenon led Spearman to propose his single factor theory of general intelligence.
12. False, it is the other way around, Gf declines from about age 27 onwards.
13. True, tests towards the centre of his radex are complex, those towards the outer edge are less complex. Tests are arranged around the circumplex in terms of content.
14. False, it was Gardner's firm view that there are multiple independent intelligences.
15. False, the three intelligences listed in Sternberg's triarchic theory are analytic, creative, and practical.
16. False, he used mostly observational methods and was not interested in individual differences but in how children learned to think
17. True, abstract thought is the most complex of the operations that we master in the course of intellectual development.

18. True. Such comparisons are possible across species but there is little scientific evidence that brain size in humans is related to intelligence.
19. False. Studies show that only in situations where people are lacking certain vitamins in their diets, will daily supplements containing the missing vitamins lead to increases in intelligence. Such situations are not likely to occur for most people in developed societies.
20. False. Genetic influences play a part, but environment is also a very powerful determinant of intelligence.
21. True (or false, depending on how well you have argued your case). It is true that as a group, our children are scoring much higher on tests of intelligence than we did, especially tests requiring fluid abilities. Whether that means they are smarter is a difficult question to answer. In Hebb's terms, they certainly have a higher Intelligence C. In Cattell's terms, they have higher fluid intelligence.

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Gerard Fogarty completed a BA (Hons, Psychology) degree at the University of New England in 1973. He then completed a Diploma of Education and taught English and History for three years at Cabramatta High School in Sydney's Western Suburbs in preparation for further training as a school counsellor. After completing these teaching years, he enrolled in a PhD at the University of Sydney, working with Dr Lazar Stankov on a thesis that explored aspects of the structure of human intelligence. Dr Fogarty left Sydney University in 1984 to take up a position with the head office of the AMP society where he supervised the development and validation of a new computerised selection system for the 5,000 strong fieldforce of the AMP, a system that includes tests of intelligence, personality, and interests. Dr Fogarty joined the University of Southern Queensland in 1988, where he is still working as Head of the Department of Psychology, and lecturing on statistics and psychological measurement. He has published many articles in the areas of intelligence and the validation of psychological tests.