Intelligence 13

CHAPTER OUTLINE

Learning Objectives

By the end of this chapter you should appreciate that:

- there is intense controversy surrounding both the construct of intelligence and its measurement (IQ), which goes back over a century and continues today;
- the central discovery of recent research in intelligence is the attribute we call general intelligence (*g*);
- general intelligence may be related to a property of the brain that we can best summarize as speed of information processing;
- various theories attempt to accommodate the relationship between general intelligence and more specific abilities, each testing their theory by trying to explain 'exceptions' to normal intellectual development, such as mental retardation and the *savant* syndrome;
- IQ appears to have a reliable genetic component, but there is ongoing controversy regarding the relationship between race, genes and intelligence;
- there are other important defining characteristics of a person in addition to their 'intelligence'.

INTRODUCTION

If someone could offer you a pill to make you more intelligent – would you take it? How would your life change if you woke up one morning with a 20 point increase in your IQ? Are you using the full extent of the intelligence you have? Answering these questions requires us to reflect on what we think intelligence is, what it 'does' and how important it is in our lives.

Psychologists have been puzzling over what intelligence is for a long time. So, too, have parents, teachers, employers and philosophers.

Why do we care so much about intelligence? Perhaps because it reaches to the heart of our conceptions of ourselves as rational beings set apart from all other animals. 'I think therefore I am', declared French philosopher René Descartes (1596–1650), capturing the broad sense in which intelligence has perhaps always been fundamental to our notion of human nature. More pragmatically, intelligence and intelligence tests have implications for our lives in terms of selection, advancement and exclusion in a range of domains.

In this chapter we will visit key historical milestones in the study of intelligence before presenting current challenges in this arena. The territory we traverse ranges from the genius of Mozart to the *savant* (i.e. 'intellectually handicapped genius') and from affirmative action policies in the workplace to eugenics (the science of selective breeding of human beings for 'desirable' traits).

SETTING THE SCENE

Questions of intelligence

Parents and teachers will both tell you that they notice differences in the rate at which siblings or classmates complete their work and progress from one level of learning to another. At one extreme, some children apparently have pervasive difficulty in completing daily tasks, while at the other extreme are children who seem 'gifted', excelling at almost everything. Think back to your own schooldays, and you will probably recollect a growing awareness of where you 'fitted in' relative to your classmates – in other words, which classmates tended to do better than you on maths and English tests and which would come to you for help with their homework.

Parents want to know if their child is capable of learning more than they appear to be. They want to know whether problems experienced by their child at school are due to a general inability to keep up with their classmates, or due to a specific area of skill deficit (such as a difficulty mastering reading), or perhaps a personality style or 'motivational' factor and nothing to do with intelligence at all. Teachers want to know the answers to a number of important questions; for example, (a) how to give each child the best learning environment, (b) whether lessons should be targeted to a child's preferred learning style and (c) whether all children can learn the same things if given enough time.

Businesses, too, spend large sums of money each year on training new staff, so they want to know which candidates are most likely to learn quickly and accurately the skills and knowledge required to complete their jobs. Some companies also want to know how flexible potential employees are likely to be in dealing with new problems. They want to know whether the person who will 'act most intelligently' in one position will also act most intelligently in another. Is the best person for the job the one with the college degree or the one with only a basic formal education but ten years' experience working her way up from the factory floor?

Our concern with intelligence leads to endless questions. For example: Can intelligence be effectively measured? What do traditional intelligence tests measure? Is intelligence one thing or made up of many different abilities? Was Einstein's intelligence of the same kind as Mark Twain's, Leonardo Da Vinci's or Helen Keller's? Are we born with a fixed amount of intelligence? Are the same people who were smartest at school still smartest as adults? Are they the most successful? Is intelligence changed dramatically by education and culture? (Who do you think is more intelligent – Aristotle or a current undergraduate physics student whose understanding of the physical world is clearly superior?)

Is it possible to compare the intelligence of different racial groups? If you placed Anglo-Saxon Australian children from the city into a remote Aboriginal community in central Australia, would they perform as well on local tests of judgement and reasoning as children of the same age from that indigenous community? Would they know how to find water in a desert terrain or how to find a goanna? Probably not – but does that mean they have become less intelligent all of a sudden? Which group would we expect to perform better on conventional tests of spatial ability or verbal reasoning? If we do compare groups, do any differences have a genetic or cultural root? Does intelligence 'run in families'? This chapter will address the core issues in understanding intelligence that bear upon these questions beginning with the notion of individual differences in intelligence.

Galton and individual differences

Francis Galton can be credited with the first systematic, scientific attempt to both understand and measure human intelligence (see chapter 1). Galton's essential idea was that there are stable, biological differences in intelligence between people.'I have no patience with the hypothesis . . . that babies are born pretty much alike, and that the sole agencies in creating differences between boy and boy, and man and man, are steady application and moral effort,' he wrote. 'The experiences of the nursery, the school, and of professional careers, are a chain of proofs to the contrary' (1892, p. 12). Galton considered intelligence to be a low-level property of our nervous system that we inherit from our parents. He believed that individual differences in intelligence reflect differences in the efficiency of operation of simple neural processes.

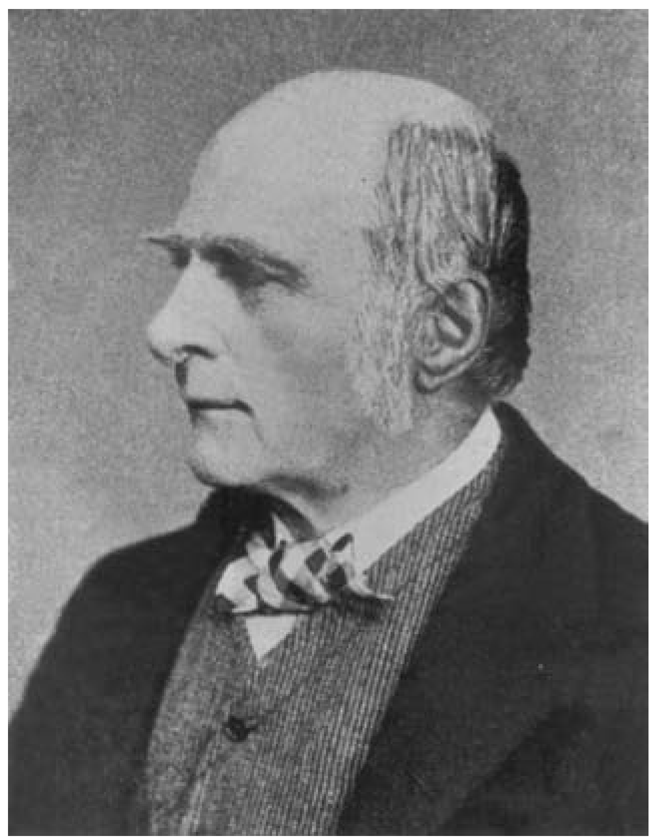

Figure 13.1

Francis Galton believed that biology has a large part to play in level of intelligence.

Galton pursued his theory in several ways – first, by constructing extensive family trees of 'persons of reputation' in one domain or another to investigate patterns in eminence and achievement within families. His book *Hereditary Genius*, first published in 1869, presents family trees of 'Commanders, men of Literature and of Science, Poets, Painters and Musicians of whom history speaks' to support his hypothesis.

Normal distribution

Another of Galton's contributions was to bring statistical understandings from the physical sciences to the study of psychology – particularly, the notion of normal distribution (see chapter 2). Galton noted that for any of our 'natural gifts' (physical, temperamental or intellectual) there will be an 'average' amount of that feature, to which most people approximate. Then, as we consider scores increasingly higher or increasingly lower than that 'average score', there will be fewer and fewer people registering those scores. Galton explains it as follows:

> Suppose a million of the men . . . stand in turns, with their backs against a vertical board of sufficient height, and their heights to be dotted off upon it . . . The line of average height is that which divides the dots into two equal parts . . . The dots will be found to be ranged so symmetrically on either side of the line of average, that the lower half of the diagram will be almost a precise reflection of the upper. (1892, 27–8)

The idea here was that, in this group, there would be many men of about average height (say 160cm) and increasingly fewer men as we approach 190cm, and similarly fewer as we approach 130cm.

Studying the normal distribution of psychological characteristics such as intelligence enables us to estimate attributes within a group and to have a point of comparison for an individual's abilities. So, we expect that most people will approximate average intelligence, and there will be a small but predictable number of people of exceptionally high intelligence and an equally small and predictable number will be severely mentally disabled.

Correlation

correlation the extent to which two variables, such as weight and height, are related; a correlation of +1 indicates a perfect positive association, and −1 a perfect negative association

Galton also introduced the idea of 'co-relation' (Galton, 1888), or *correlation*, which is a measure of the extent to which two variables, such as weight and height, are related. A correlation of +1 would reflect a perfect positive relationship between the two variables – as height increases, so weight increases in direct proportion. But we know from our own experience that there is not necessarily a perfect relationship (there are some short, heavy-set people and some tall, skinny people) so the correlation between weight and height is likely to be less than one but still positive. A correlation of –1 would reveal a perfect negative relationship, where an increase in scores on one variable is directly related to decreasing scores on the other – for example, the number of cigarettes smoked is negatively correlated with life expectancy.

Together, the notions of normal distribution and correlation allow us to consider how our abilities vary in relation to each other and in relation to the abilities of others in the population, and how well we can use scores on one variable to predict scores on another.

Early attempts to measure intelligence

In his Anthropometric Laboratory in London in the late nineteenth century, Galton attempted to measure a range of attributes that show individual variation. These included physical attributes such as head circumference, height and hand size, as well as intellectual characteristics (which, remember, he believed were a function of neural processes). These intellectual measures included basic sensory-motor tasks, such as speed of reaction to sounds and visual stimuli. Galton then compared these innovative measures of 'intelligence' to subjective estimates of the intellectual prowess of his participants based on their 'reputation' and eminence in the family tree (There were no such things as intelligence tests at the time!). Unfortunately, his empirical efforts were not successful.

Subsequently, Charles Spearman (1904) set out to estimate the intelligence of 24 children in his village school. He discovered a relationship between each child's performance in a number of domains (including teachers' ratings of 'cleverness' and ratings by other students of their 'common sense out of school') and measures of their ability to discriminate light, weight and pitch. In other studies, he found strong associations between scores on examinations in different subject areas such as classics and maths. Linking together these strands of evidence, Spearman concluded that there was a 'general' intelligence underlying performance on these very different tasks. He regarded general intelligence, or *g*, as a unitary, biological and inherited determinant of measurable intellectual differences.

In apparent contradiction, Spearman also noted that there were some 'specific abilities', such as musical aptitude, that contributed to differentially exceptional performance in specific areas and seemed less related to performance in other disciplines. But his finding of a general feature that underlies performance in many areas was so radical that it became the hallmark of his work. Spearman likened *g* to mental energy – a limited resource available to all intellectual tasks. So the idea was that individuals differ in general intelligence because they have different amounts of this mental energy.

Binet and developmental changes

In contrast to Galton and Spearman, Alfred Binet focused on the universalities of human intellect. He proposed that we all pass through certain developmental stages, and that to understand these stages we should consider the 'higher faculties' of the mind rather than 'low-level' neural processing: 'It seems to us that in

Pioneer

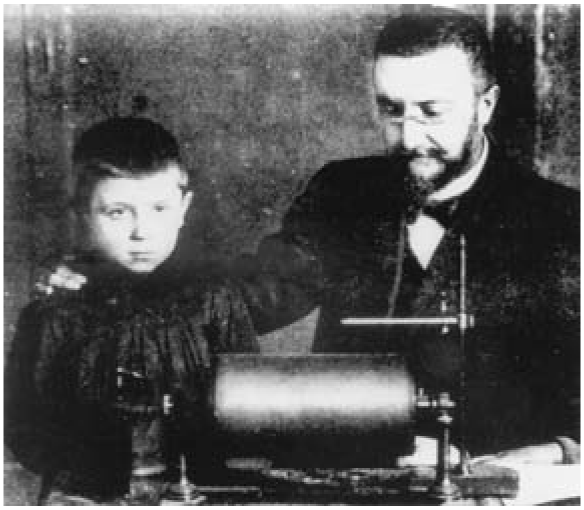

Figure 13.2

Alfred Binet's focus was on the development of intelligence with an emphasis on the roles of reason and judgement.

Alfred Binet (1857–1911), a French lawyer and self-trained psychologist, came to the field of intelligence via a study of psychopathology, free will and hypnosis. His interest in intelligence was prompted by observation of his two daughters, Madeleine and Alicia. While he was interested in how their different personalities affected their understandings of the world, he also noted that with age came the ability to reason about events in increasingly abstract ways. Binet observed their performance on various puzzles and asked them to explain how they had solved them. He was fascinated with their different approaches. This informal case study methodology led to the development of intelligence tests as we know them today.

intelligence there is a fundamental faculty. . . . This faculty is judgement, otherwise called good sense, practical sense, initiative, the faculty of adapting oneself to one's circumstance' (Binet & Simon, 1916, pp. 42–3). An emphasis on reason and judgement is perhaps not surprising given Binet's formal training as a lawyer.

The first intelligence tests

In 1904, Binet was charged by the Parisian authorities to develop tests that would identify children in need of special education, without relying on the subjective reports of parents or teachers. So he set about finding a way to construct tests with objectively verifiable scales of difficulty that could measure rates of development in 'higher mental processes'.

Binet's technique for constructing the first test was based on an important insight: whatever intelligence is, we can be sure that it changes (develops) with age. So the first intelligence test was based on the central idea that the age at which the 'average child' can succeed at a particular problem is an indication of the difficulty of that problem. Using this yardstick, children can be characterized as 'average', advanced or delayed in their rate of development compared to their peers.

Binet and his associate Théodore Simon used a range of tasks in their first intelligence tests. These included around 30 items of increasing difficulty, beginning with simple items that even children with intellectual disabilities were able to complete (such as following a lighted match with your eyes and shaking hands with the examiner). More complex tasks included pointing to body parts and defining words such as 'house' or 'wheel', and tasks that were harder still, such as repeating back strings of digits and constructing sentences involving several specified words.

Interestingly, vocabulary and digit recall tasks are still used in our most advanced intelligence tests today. Binet was also the first psychologist to specify that such tests must be:

1. administered and scored in a careful and *standardized* manner if comparisons between children's performance are to be valid and reliable;
2. presented in the same order to all children and in order of increasing difficulty so that each child can pass as many tests as possible; and
3. administered in a one-to-one setting and only where the examiner has first established a friendly rapport with the child.

Psychologists still adhere to these very important principles of testing today.

IQ and the birth of psychometrics

Later, Binet used the idea of the average age at which a task was mastered to derive a child's *mental age* – a radically new concept. Mental age (MA) is equivalent to the chronological age (CA) for which any test score would represent average performance. So a child scoring better than the average child of his age would have a higher MA than CA, and a child scoring lower than average would have a lower MA than CA.

It took one short step, by Stern (1914), to derive an index of differences in intelligence within ages. The resulting intelligence quotient, or IQ, was calculated using the classical formula, $IQ = MA/CA \times 100$. The calculation of IQ gave birth to two ideas:

1. individual differences in intelligence can be expressed by a single score (note that this notion of a single score actually presumes the existence of *g*); and
2. a range of measures of performance on different kinds of knowledge, judgement and reasoning tasks (as evaluated by tests such as Binet's) can be taken together to contribute to our understanding of intelligence.

Psychometrics or the measurement of human abilities (later extended to other attributes) was therefore born. Stern's formulation helped to drive a wedge between the two different approaches to studying intelligence – the individual differences method (concerned with IQ differences among peers) and the developmental method (concerned with changes in MA with CA). And this wedge finally culminated in these different research approaches being split apart through the work of Jean Piaget.

Piaget and the importance of error

Piaget's early career involved further developing Binet's tests and included some collaboration with Binet's associate Théodore Simon. His genius was to realize that errors on intelligence tests might be even more informative than the total test score used in Binet's calculations of MA. By contrast, at the same time psychometricians became further interested in developing better measures of individual differences in *g* (expressed in terms of test scores). They focused largely on the structure of adult intelligence, which was generally considered to be fully developed.

On the other hand, Piaget's approach – inspired (like Binet's) by observation of his own children – was to focus more on the kinds of errors made by children of different ages. Piaget took these to be indicators of the universalities or commonalities in underlying cognitive structures at different stages of cognitive development. The rate of cognitive development was thought to vary between children, but with all children eventually passing through these same stages. In due course, Piaget developed his own tests based on his stage theory of cognitive development (see chapter 9).

Back to the future: the intelligence landscape

Both Binet and Galton died in 1911. In the century since, in terms of *psychological practice*, Binet's conception of intelligence has dominated over Galton's and Spearman's, and has shaped the content of the current intelligence tests that are used in the Western world today. The Binet–Simon scale was even selected by the prestigious journal *Science* as one of the 20 most significant discoveries and developments of the twentieth century. Lewis Terman developed this scale further at Stanford University to produce the Stanford–Binet – a test still widely used today.

Both Binet and Galton have had a significant influence on social policy. Binet's test was used for placement of children into classes supporting remedial education with a view to improving their life options. Unfortunately, others (including Terman) have supported the use of IQ tests to segregate children (and adults) without any intention of working to improve their circumstances or opportunities. Galton's work in the eugenics movement supported highly controversial social policies, such as recommending immigration to Britain for select talented people, enforced sterilization of women with low IQ scores, and social segregation on the basis of racial differences in IQ.

On the other hand, the theoretical and empirical contribution of both men has been to sketch out the landscape for the ongoing debate about the nature of intelligence. The key questions raised by Galton and Binet remain questions of interest today. Indeed, a quick check in a recent edition of the pre-eminent journal *Intelligence* revealed:

a) arguments about the relative importance of general intelligence and specific cognitive abilities (Brody, 2003a; 2003b; Gottfredson, 2003; Sternberg, 2003);
b) studies of twins and adopted siblings exploring the relative contribution of genes and environment to the development of general intelligence (Spinath, Ronald, Harlaar, Price with Plomin, 2003);
c) consideration of the efficacy of information-processing measures of general intelligence (Bates & Shieles, 2003; Burns & Nettelbeck, 2003); and
d) comparisons of age group differences in intelligence with racial group differences (Jensen, 2003).

These recent papers reflect many of the central issues raised by Galton and Binet – we will here examine contemporary developments in each of these areas.

GENERAL INTELLIGENCE – MULTIPLE ABILITIES

How is the intellect structured?

Following the development of the first standardized intelligence tests, it was thought that data from test performance might reveal the secret of how the intellect is structured.

Intelligence as a general mental facility

Initial studies looked definitive. If a random sample of participants take different types of cognitive tests, such as those in the Binet–Simon scale or the more recent Wechsler intelligence scales, those who are better than average on tests of vocabulary will generally be better than average at mechanical reasoning. They will also be better at solving analogies, making inferences and carrying out arithmetical calculations, know more general information, be faster at substituting digits for other symbols, and so on.

The fact that the correlations between ability tests are all positive has been termed *positive manifold*. In other words, different tests may well tap similar underlying factors or traits, as Binet had suggested. So it seemed that perhaps geniuses as diverse as Einstein and Mark Twain might have something in common after all. This model suggests that, rather than there being different types of intelligence, differences between these men may have more to do with the application of a general mental facility to different areas of interest.

positive manifold the fact that the correlations between ability tests are all positive

Research close-up 1

Can we raise intelligence?

The research issue

Our models of intelligence affect the way we interpret intelligence test performance and help to answer philosophical questions about human nature. But they also matter in psychological practice where we have a responsibility to validate our theories before they are put into practice to ensure that we 'do no harm' – the first ethical principle of being a psychologist.

There have been instances in the past of theories about causes underlying intellectual deficits leading policy makers and educators down unhelpful paths. For example, at one time, people with low IQ were locked in asylums with no effort at remediation or maximization of potential. Today, there are ongoing debates about integration of children with Down's syndrome into regular classrooms. While some people believe this 'elevates' the child's intelligence, others argue that it places the child under unreasonable pressure.

In answering questions like this, perhaps we need to consider the central issue of whether it is possible to improve our intelligence. There have been many attempts to do so. The Carolina Abecedarian Project (www.fpg.unc.edu) is one example of a scientifically controlled study exploring the potential benefits of early childhood educational intervention programmes for children from poor families who were considered to be at risk of environmental or 'cultural–familial' mental retardation.

Design and procedure

Beginning in 1972, each of 111 children received nutritional supplements and referral to social services as needed. Additional educational intervention was provided to 57 of these children in a full-time childcare setting from infancy to age five. Each child had an individualized programme of educational activities presented as 'games' throughout the day, focusing on social, emotional and cognitive development. Children's progress was monitored over time and into adulthood (Campbell & Ramey, 1994, Campbell et al., 2002).

Results and implications

Results suggest that children in this study completed more years of education and were more likely to attend college, they were older (on average) when their first child was born, and their own mothers achieved higher educational and employment status than those whose children were not in the programme. These results seem especially pronounced for the children of teen mothers. A cost–benefit analysis estimated a 4:1 financial return on the cost of the programme in terms of savings from poor predicted outcomes for this population (Masse & Barnett, 2002). And yet, importantly, when the results were carefully evaluated, no increase in measured IQ was found (Spitz, 1999).

This research suggests that even when significant environmental factors contribute to intellectual impairment (perhaps through lack of opportunity for learning), structured educational intervention does not lead to general improvements in IQ. Similarly, in early intervention studies focusing on children with specific organic intellectual disabilities, such as Down's syndrome, changes in IQ do not typically occur following early intervention, despite many optimistic reports. See Spitz (1999) for a critical review of methodology in studies targeting changes at both ends of the IQ spectrum.

Does it follow that special educational opportunities are pointless for children with low IQ, as some researchers have suggested (e.g. Howe, 1998)? No, it does not. What does change as a result of such programmes is behavioural repertoire, levels of functional daily skills and the range of applications of knowledge through repetition and reinforcement across contexts. Such changes can have an enormous impact on quality of life for participants and their families. These interventions provide an opportunity to maximize the use of the cognitive resources available to the child. As outlined in the Abecedarian Project, there may also be important social welfare outcomes.

Campbell, F.A., & Ramey, C.T., 1994, 'Effects of early childhood intervention on intellectual and academic achievement: A follow-up study of children from low-income families', *Child Development*, 65, 684–98.

Campbell, F.A., Ramey, C.T., Pungello, E., Sparling, J., & Miller-Johnson, S., 2002, 'Early childhood education: Young adult outcomes from the Abecedarian Project', *Applied Developmental Science*, 6 (1), 42–57.

Howe, M., 1998, 'Can IQ change?', *The Psychologist*, February, 69–71.

Masse, L., & Barnett, W.S., 2002, *A Benefit–Cost Analysis of the Abecedarian Early Childhood Intervention*, National Institute for Early Education Research (accessed at http://nieer.org/resources/research/AbecedarianStudy.pdf, May 2004).

Spitz, H.H., 1999, 'Attempts to raise intelligence' in M. Anderson (ed.), *The Development of Intelligence*, Hove: Psychology Press.

Underlying mental traits

The question then becomes: how many (or how few) underlying traits are there, which explain most of the difference in scores we find on a whole battery of tests? This is what psychologists hoped to find out using *factor analysis* – a statistical technique developed by Charles Spearman specifically for this purpose. Factor analysis is a complex mathematical technique for identifying how many 'factors' underlie a large number of individual pieces of data, and its exploration is best left to a more advanced, dedicated statistics text. However, it is relevant to mention here that two different, but equally sound, approaches to factor analysis have led to fierce debate about the number of basic elements of intelligence.

factor analysis a data reduction technique where relationships between a large number of variables can be reduced to a relationship among fewer hypothetical (i.e. latent) factors

The original factor solutions obtained by Spearman found a general factor of intelligence (g) and some specific factors. But Louis Leon Thurstone (1938) argued that, rather than a single general intelligence, there are seven 'separate and unique' primary mental abilities: word fluency, number facility, verbal comprehension, perceptual speed, associative memory, spatial visualization and inductive reasoning.

Horn and Cattell (1966) identified two factors, which they labelled *fluid intelligence* (*Gf*) and *crystallized intelligence* (*Gc*). Unlike Thurstone, Horn and Cattell believed that these different aspects of intelligence were differentially important. *Gf* seemed to represent something akin to Spearman's *g*, namely an overarching processing capacity that in turn contributed to *Gc*, which represented diverse skills and knowledge acquired across the lifespan. There is some evidence to support this conceptualization of intelligence, as tests that tap these two different aspects of intelligence (*Gf* and *Gc*) seem to be differentially related to ageing.

fluid intelligence (*Gf*) Horn and Cattell's *Gf* is something akin to Spearman's *g*, namely an overarching processing capacity that in turn contributes to *Gc* (see **crystallized intelligence**)

crystallized intelligence (*Gc*) diverse skills and knowledge acquired across the lifespan

The current consensus

After decades of debate, Carroll (1993) and the American Psychological Association Task Force on Intelligence (1996) concluded that there is now a strong consensus among psychometricians that the inclusion of a *g* factor leads to a better factor structure when attempting to interpret findings obtained from ability testing. This outcome is partly based on the fact that Thurstone's 'primary mental abilities' themselves correlate with each other. The same is true for Horn and Cattell's crystallized and fluid intelligence. This allows these constructs to be factor-analysed, in turn producing a general factor (i.e. a factor that all the original tests are correlated with) – something that Thurstone himself acknowledged.

Speed of Information Processing as a Measure of Intelligence

Studies of reaction time and inspection time

In the 1970s Arthur Jensen began a research programme investigating the possibility that intelligence, or psychometric *g*, is based on the speed with which we process information. Jensen thought that the latter might be measured without asking any of the conventional questions found in intelligence tests, thereby avoiding concerns about cultural bias (more about that later).

To measure speed of processing, Jensen used a very simple *reaction time* (RT) procedure, in which participants have to respond quickly to the onset of a light (see figure 13.3). He found that individuals with higher IQs respond faster and are more consistent in the speed of their responses. Jensen (1982) claimed that the basis of individual differences in intelligence is to be found in the speed with which we process a single bit of information (as evaluated, for example, by his *speed of information processing* task). Jensen proposed that this capacity may be underpinned by the rate of oscillation of excitatory and inhibitory phases of neuronal firing (see chapter 3).

reaction time (RT) the time taken to process a single bit of information: the stimulus is seen until a decision is made and response is completed

speed of information processing the speed with which an individual can take in information from their environment; the speed of perceptual encoding.

While these findings were exciting, reaction time experiments were subsequently criticized on the basis that the response time could be confounded by the speed or organization of motor responses and task strategies, rather than being a pure measure of speed of intellectual processing.

In the 1970s an Australian researcher, Doug Vickers, addressed this concern by developing the *inspection time* (IT) task (see Research close-up 2), in which it does not matter how long participants take to respond to a presented stimulus, so motor organization is no longer an issue. Instead, the length of time they are exposed to the stimulus is controlled by varying the time of stimulus presentation before the onset of a following masking stimulus (this is a figure that effectively destroys the information from the target stimulus). Interestingly, the decision task itself does not get any more complex – it is only the decreasing exposure duration that makes the task increasingly difficult.

inspection time (IT) the time taken to process a single bit of information: the stimulus is seen (inspected) for a very short time before disappearing

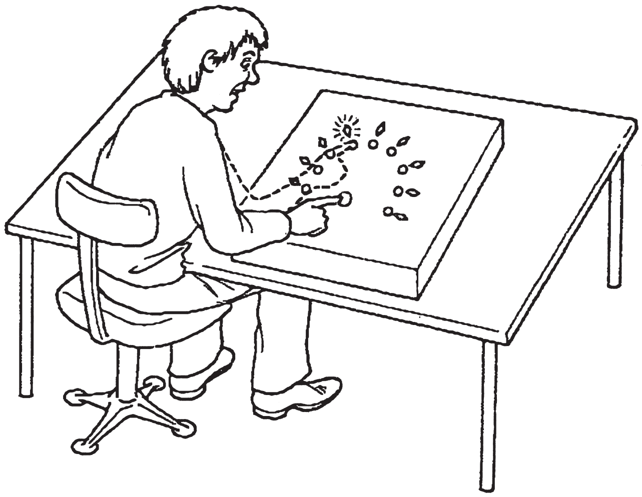

Figure 13.3

One measure of speed of processing. This shows the apparatus used by Jensen and colleagues. When one of the peripheral lights comes on the child must lift his or her hand from a central home button and press the button beneath the light as quickly as he or she can. Source: Anderson (1992).

Pioneer

Arthur Jensen (1923–) articulated an influential body of thought regarding IQ and processing speed. In the 1970s, Jensen began a research programme investigating the possibility that intelligence, or psychometric *g*, is based on the speed with which we process information. To measure speed of processing, Jensen and his colleagues used a very simple reaction time task. They found that individuals with higher IQs responded faster and were more consistent in the speed of their responses. The application of the reaction time technique to the study of IQ has since been criticized, but it has stimulated a considerable volume of work in related areas, such as in the use of inspection time as a complementary methodology. Jensen has also written controversially on the topic of IQ and race.

The IT task was made simple enough for children with intellectual disabilities to discriminate between two line lengths after seeing the stimulus for only 200–300 ms. Participants with higher IQs can make the discrimination at shorter exposure durations – that is, they have shorter inspection times of around 100 ms. Child-friendly versions of the inspection time task use 'space-invader' type computer games, where the discrimination relates to the relative height of an alien's antennae (Anderson, 1988; Scheuffgen et al., 2000).

In careful reviews of many studies, Nettelbeck (1987) and Kranzler and Jensen (1989) came to the conclusion that inspection time and IQ correlate negatively at about −0.5. In other words, the speed of processing a 'simple' unit of information predicts about 25 per cent of the individual differences we find in intellectual performance, as measured by a typical intelligence test. (Note, the square of a correlation, r^2, indicates the shared variance between two variables.) Inspection time continues to be of great interest in helping us understand the nature of intelligence (Burns & Nettelbeck, 2003).

How fast is your nervous system?

In parallel with these studies, there has been challenging research on physiological correlates of intelligence. Much of this research was championed in its earliest stages by Hans Eysenck (1988), who was also exploring physiological correlates of personality at the time, and with whom Jensen had worked (see chapter 14).

Research has found correlations between IQ and brain evoked potentials (Deary & Caryl, 1993), cerebral glucose metabolism (Haier, 1993) and nerve conduction velocities (Reed & Jensen, 1991, 1992). Deary and Caryl (1997) provide a comprehensive and positive review of the evidence for a physiological basis to differences in intelligence, although some researchers remain unconvinced (Howe, 1997). There is also a growing swathe of brain-scan studies which use magnetic resonance imaging to examine neural activation changes during thoughtful activity in healthy control participants and in patients with diseases such as Alzheimer's, which affects intellectual functioning.

Considered together with the robust evidence from inspection time and reaction time studies, the hypothesis that a biological variable might form the basis of general intelligence has received increasing support. This variable is best thought of as reflecting differences between individuals in the speed or efficiency with which information in transmitted in the nervous system.

Non-unitary theories of intelligence

Gardner's theory of multiple intelligences

Ever since Thurstone (1938), there has been a long series of challengers to Spearman's unitary conception of intelligence. Probably the most influential is Gardner (1983), an educationalist who believes that the classical view of intelligence reflects a Western bias towards logical reasoning, which in turn is reflected in our educational system.

Whether we are considering intelligence in terms of processing capacity, or considering Thurstone's primary mental abilities, or reviewing the tasks that are routinely included in intelligence tests, Gardner believes that we typically only focus on a narrow range of logico-mathematical abilities. His theory of *multiple intelligences* accounts for the diverse

multiple intelligences Gardner's theory that there are many autonomous intelligences including linguistic, musical, logical–mathematical, spatial, bodily–kinaesthetic, personal, naturalist and spiritualist

Research close-up 2

A classic study using inspection time

The research issue

Nettelbeck and Lally (1976) were the first to use inspection time in research on intelligence. The hypothesis was that differences in speed of information processing might underlie IQ differences. This experiment aimed to take a novel index of the speed of perceptual encoding and examine whether 'more intelligent' people encode information faster than do 'less intelligent' people.

Design and procedure

Ten male participants aged 16–22 years with a mean IQ of 83 (range = 47–119) took part in the study. Three of the participants with the highest IQs were referred for the study because of problems associated with minor injuries or for assistance with behavioural problems. The seven with the lowest IQs were referred because of their inability to cope with open employment.

The stimuli were drawn on cards and presented to the participant using a *tachistoscope* – a device that allows very fast presentation of visual material. (Nowadays, stimuli are presented on computer monitors.) The stimuli were two vertical lines of markedly different lengths joined at the top by a short horizontal bar. For one type of stimulus, the shorter of the lines was on the left, and for the other type it was on the right (see figure 13.4).

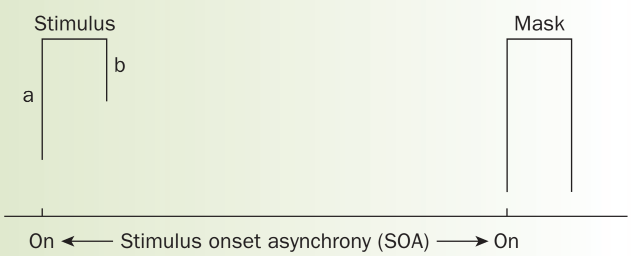

Figure 13.4

A second measure of speed of processing. This shows the typical stimulus used in an inspection time task. Here participants must decide which line in the figure is the shortest (line *b* on the right). The task is made difficult by having a short stimulus presentation, which is terminated by a masking stimulus. Source: Anderson (1992).

The participants simply had to decide whether the long line was on the left or the right of the stimulus. The task was made more difficult by covering up the stimulus with another card that showed two lines of equal length that were thicker and longer than the longest line in the test stimuli. In this way, the second card acted as a 'backward masking' stimulus that destroyed the information contained in the first test stimulus.

The exposure duration of the test stimulus for each trial was manipulated by varying the time between the onset of the test stimulus and the onset of the masking stimulus (stimulus onset asynchrony, or SOA). On each trial, the participant had to press a key to indicate whether the short line on the test stimulus was on the left or on the right.

Participants were given 105 trials of different exposure duration in each testing session. The first five trials were for practice only, and were excluded from subsequent analyses. The importance of accuracy rather than speed was emphasized. For each participant an inspection time was extrapolated from the data relating accuracy to SOA in order to estimate the shortest exposure required for 97.5 per cent accuracy in decision making.

Results and implications

Estimates of inspection time correlated −0.92 with performance IQ (PIQ) derived from administration of the Wechsler Adult Intelligence Scale (WAIS), but, interestingly, the relationship with verbal IQ (VIQ) derived from the WAIS was not statistically significant. So the study showed that a very simple measure of perceptual speed is related to IQ differences, although this association was specific to one form of IQ (i.e. performance rather than verbal IQ). Subsequent research has suggested that PIQ has a higher visual-spatial component than does VIQ, which might explain this finding.

By today's standards, this study is methodologically weak – there are too few participants, too many of them have low IQ for a study that hopes to extrapolate to normal variation in intelligence, and the psychophysical procedures are less than perfect.

But the basic relationship with IQ observed here has held up, with meta-analyses suggesting that the correlation is about −0.5. So inspection time as a task has become a cornerstone of theories proposing that differences in general intelligence might be due to global differences in speed of information processing.

Nettelbeck, T., & Lally, M., 1976, 'Inspection time and measured intelligence', *British Journal of Psychology*, 67 (1), 17–22.

range of important adult capacities by considering a diverse range of abilities, each of which he values as highly as traditional conceptions of 'intelligence'. Gardner lists these autonomous intelligences as linguistic, musical, logical–mathematical, spatial, bodily–kinaesthetic, personal, naturalist and spiritualist (Gardner, Kornhaber & Wake, 1996). Each is manifested, suggests Gardner, in culturally relevant 'intelligent' behaviours, with normal adults having differing profiles of relative strengths and weaknesses across these intelligences.

Gardner's abilities were identified from a diverse body of evidence, including:

- the selective damage of individual abilities through brain damage;
- the existence of otherwise very low-IQ individuals who display extremely well-developed ability in one intelligence (*savants*);
- examples of excellence in one domain but ordinariness in another (e.g. Mozart was a musical genius but struggled in many other aspects of life); and
- the constraint that the ability should be culturally valued and have a plausible evolutionary and developmental history.

Gardner's multiple intelligence model made a significant impact in the field of education, with schools developing broader and more responsive approaches to assessment, and a more diverse curriculum to help develop individual intelligences in each student. But not only is Gardner alone in claiming that there is no general factor of intelligence, he also provided no theoretical specification of what any of his proposed intelligences constitute, or how they work at any specific level of description – social, cognitive or biological (see Anderson, 1992). This makes gathering evidence for the theory of multiple intelligences problematic. Although it is a challenging and somewhat appealing idea, there is no evidence for true autonomy of intelligences either – rather the reverse. As we have seen, as per the earlier theorizing of Charles Spearman, diverse abilities are generally correlated.

That said, the idea that there is more to intelligence than *g* alone is now generally accepted. The challenge for the future is to develop a theory that makes *g* compatible with the observed degree of specificity in intellectual functioning that has been outlined as evidence by Gardner. Finally, Gardner's desire to emphasize the value of a diverse range of human talents is laudable, but attempting to achieve this by re-naming them 'intelligences' can lead to confusion and errors in application. For example, we may encourage unrealistic expectations of people if we adopt the position that there is a genius in us all and we just need to find our hidden gift – paradoxically we may put children under pressure to 'find their intelligence'. While it is a truism to say that we all have our strengths and weaknesses, few of us will truly excel, even with concentrated application in one domain.

A hierarchical structure for intelligence

Sternberg (1984, 1985) also proposed a non-unitary theory – the triarchic theory of intelligence. Like Gardner, he proposes several types of intelligence: analytical intelligence (which approximates the traditional notion of *g*); creative intelligence (which involves insight, synthesis and the ability to respond to novel situations); and practical intelligence (which involves the ability to solve real-life problems). But in his theory Sternberg attempts to go beyond this to explain how these intelligences work. He suggests that each kind of intelligence involves a control hierarchy of *cognitive components* that contribute to our 'mental self-management' – these include a) performance components, b) knowledge acquisition components and c) metacomponents.

cognitive components basic information-processing routines (e.g. encoding, response selection) which underpin task performance

At the bottom of the hierarchy are the elemental performance components. These are the information-processing mechanisms involved in the execution of any task and invoked by a particular sequence of operations, such as encoding, inference and response selection. Sternberg came to the conclusion that although performance components contribute to individual differences in intelligence, overall the contribution is weak, with correlations rarely exceeding 0.3. Knowledge acquisition components are those processes involved in the gaining and storing of information – processes such as memory – and in turn, these components will evolve performance components in the service of their own functions.

At the top of Sternberg's processing hierarchy are metacomponents. These are executive processes responsible for planning task solutions and monitoring feedback from performance and knowledge acquisition components. Sternberg claimed that the major individual differences related to intelligence are found in these metacomponent processes. In other words, intelligence is the province of the processes principally involved in problem-solving strategies (high-level components) rather than the information processing (low-level components) that implements the problem-solving routines. So, for example, one of Sternberg's metacomponents is responsible for recognizing the nature of the problem set by a cognitive task.

Although Sternberg has written extensively on his theory, it reads more like a re-statement of how intelligence is manifested rather than an explanation of it. Furthermore, recent reviews of the theoretical and empirical support for the theory do not support the notion that creative or practical intelligences are as important as analytical intelligence (i.e. an approximation of *g*) in predicting life success (Brody, 2003a; Gottfredson, 2003).

INTEGRATING CURRENT ISSUES

A century after Galton and Binet, we are now making progress in developing new models that draw together some of the apparent contradictions of earlier research. And we have moved some way towards understanding both individual differences and developmental change in 'normal' intelligence, as well as in exceptional intellectual populations. Work in the field of intelligence has never been more vibrant at both the level of theory development and at the level of applied research and practice.

Our overview of new research on intelligence begins with a couple of contemporary theories. These will allow us to look at two areas of research that today are regarded as test-beds of any comprehensive theory of intelligence – *savant* syndrome and the nature of mental retardation.

But first please note that the terms ‘retarded’ and ‘mental retardation’ are being used here in a professional-technical sense with a very specific definition of measured IQ being less than 70. It is offensive to use the word ‘retard’ to refer to an individual who could be given the diagnostic label ‘retarded’, and the term ‘retard’ should always be avoided, as the intellectual abilities of such people are clearly not defining features of them as individuals.

These two cases are important in evaluating theories of intelligence because they are anomalies, that is they are exceptions in terms of intellectual ability. Any theory that comprehensively characterizes the concept of ‘intelligence’ must be able to explain what is ‘normal’ as well as that which is exceptional.

Detterman – the best of both worlds

Detterman (1986, 1987, 1996) claims to have solved the two major (and related) oppositions in the history of intelligence theory:

1. Intelligence as a low-level, global property of all intellectual operations vs. intelligence as a high-level, complex intellectual function – as we have seen already, the first view is advocated by Galton, Spearman and Jensen whereas the second is advocated by Binet, Thurstone and Sternberg.
2. Intelligence as a general ability (again as advocated by Galton, Spearman and Jensen) vs. intelligence as specific abilities (as advocated by Thurstone and Gardner).

Detterman’s solution to these oppositions is to take the ‘best of both worlds’ – general intelligence is real, but rather than being a single ‘ability’, it is better viewed as a high-level property of a complex system composed of multiple intelligences. Detterman argues that the performance of any complex task, including intelligence tests, requires a number of basic abilities. In this scheme, general intelligence represents an average of the processing of several independent components that contribute to the performance of any complex task.

This contrasts with Spearman’s proposal that there is a single ability common to all tasks and that differences in this single ability between individuals (hypothesized, for example, by Jensen to be represented by differences in speed of processing) give rise to differences in ‘general’ intelligence. Although these conceptions may sound similar, if Spearman is right, we have two important empirical predictions:

1. there should be a single task that correlates as highly with a standard measure of intelligence as measures of intelligence correlate with each other; and
2. if two tasks are correlated with a measure of general intelligence, they should also be correlated with each other.

Detterman considers that both of these predictions are falsified by actual data. Measures of basic cognitive functions in fact have low correlations with each other, and no single basic task correlates with *g* as highly as Spearman would predict. Detterman cites Guilford (1964), who measured correlations between tests that he believed reflected 150 facets of intelligence. Each test individually correlated with the general measure of IQ derived from the test battery. But a full 17 per cent of 7000 or so correlations between tests were effectively zero.

On the other hand, Deary and Stough (1997) have argued that the correlation between inspection time and IQ is high enough to support the prediction that Spearman’s *g* might be measurable by a single simple task. It is also unclear to what extent in Guilford’s studies the zero correlations between tasks were due to the different reliabilities of the elementary tests used or to the use of participants with a restricted range of abilities. Nevertheless, Detterman has pointed to a new approach to resolving what are now very old disputes in the intelligence literature.

Anderson – two routes to knowledge

Anderson (1992) attempts the same synthesis as Detterman (that is, between low-level and high-level views of intelligence, and between general and specific abilities) but incorporates a developmental dimension. Anderson’s theory is also framed within a general theory of cognitive architecture proposed by Fodor (1983).

Anderson’s theory of the *minimal cognitive architecture* underlying intelligence and development argues that intelligence tests measure intelligence by assessing knowledge, but that knowledge itself is acquired through two different routes, as proposed by Fodor. The major proposition is that these two processing routes are related to the two different dimensions of intelligence – one related to individual differences (viz Galton, Spearman and Jensen) and the other to cognitive development (viz Binet and Piaget).

minimal cognitive architecture Anderson’s model of intelligence outlining two main contributors to the gaining of knowledge: speed of information processing and modular development

Central processes of thought

Anderson suggests that the first route to knowledge is through thought (*central processes*) and is related to differences in IQ.

central processes Fodor’s term for the kinds of proposed information processing carried out in thought as distinct from those carried out by mental ‘modules’

Thoughtful problem solving can be done either by verbalizing a problem (using language-like propositions to think) or by visualizing it (using visuo-spatial representations to think). For this to happen, we need two different kinds of knowledge acquisition routines, each generated by one of two specific processors. It is proposed that these processors are the source of individual differences in specific abilities, which, in turn, are constrained by the speed of a basic processing mechanism. So, at a slow processing speed, only the simplest kinds of thoughts of either kind can occur (It is argued that the speed of the basic processing mechanism can be measured using tasks such as inspection time and reaction time.). It is suggested by Anderson that this constraint is the basis of individual differences in general intelligence and the reason for manifest specific abilities being correlated (giving rise to the *g* factor).

Information-processing modules

modules dedicated information-processing systems that provide information about the environment (e.g. complex information conveyed by people's faces) which cannot be provided by central processes of thought in an ecologically useful time frame

The second route to knowledge is through dedicated information-processing *modules*, and it is argued by Anderson that this route is related to cognitive development.

It is suggested that modules have evolved to provide information about the environment that cannot be provided by central processes of thought in an ecologically useful time frame. For example, if we had to 'think through' all the perceptual information presented to us in order to construct a three-dimensional view of the world, we would be literally lost in thought. Because this activity is so important to us and requires great computational power and speed, it is suggested by Anderson (building on Fodor) that evolution has created special modular devices to allow us to do this automatically. Anderson theorizes that this is catered for by the 'perception of 3D space' module illustrated in figure 13.5.

Other examples of likely modules are language acquisition devices, face recognition systems, and the core computational procedures involved in acquiring a theory of mind (Leslie, 1987; see chapter 9).

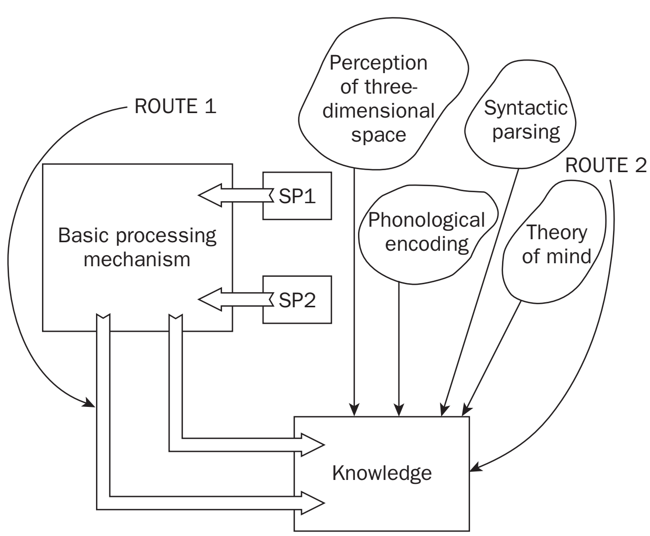

Figure 13.5

The theory of the minimal cognitive architecture underlying intelligence and development. (SP1 and SP2 denote specific processors.) Source: Anderson (1992).

According to Anderson's viewpoint, the maturation and acquisition of modules is the prime cause of developmental change. Because modules function independently of variations in the speed of the basic processing mechanism, their operation is independent of differences in IQ. This means that, according to Anderson, individual differences and cognitive development represent two independent dimensions of intelligence. It also means that these complex modular attributes are available to non-brain-damaged individuals with intellectual disabilities.

While evidence for, and application of, Anderson's model is increasing (Anderson, 2001), a theory such as this is necessarily constrained by imperfections in the tasks (such as inspection time) used to measure the hypothetical, biological basis of speed of processing. Indeed others have suggested that inspection time, for example, is more related to specific visual processes than to general intelligence (Burns, Nettelbeck & White, 1998; Deary, 2000).

What do we mean by 'mental retardation'?

As mentioned previously, mental retardation is a diagnostic category applied to individuals with an IQ below 70 in the presence of other limitations in functional skills, such as communication, self-care and social skills. People with mental retardation make up approximately 3 per cent of the general population.

Interestingly, there are more severely mentally retarded individuals (i.e. with IQs under 50) than the normal distribution of IQ strictly ought to allow. There is relatively high heritability of IQ (Bouchard et al., 1990), and it is likely that low-*g* is the major form of inherited mental retardation (Spitz, 1992). In addition, there are specific clinical etiologies, including Down's syndrome, Fragile-X, autism and Praeder-Willi syndrome, that have little in common other than mental retardation (Simonoff, Bolton & Rutter, 1996).

These characteristics support the idea that there are two distinct groups of people with mental retardation – those with known organic etiology and those who represent the low end of the normal distribution of general intelligence (Zigler, 1967, 1969). While there is a clear theoretical value in distinguishing these groups, its importance for predicting everyday behavioural competence is disputed (Burack, Hodapp & Zigler, 1990; Goodman, 1990). To put it another way, IQ is a good predictor of functional abilities no matter how it comes about, but each low-IQ group may require different approaches to education and home care.

Theories of retardation

The development debate

What of the development of intelligence in those with mental retardation? The classic debate has been framed around two views. The developmental view states that while the retarded as a group are disabled with respect to their same-age peers, they go through the same (Piagetian) stages of cognitive development (Zigler, 1969). They simply develop more slowly. The difference view, by contrast, says that there is a fundamental deficit associated with mental retardation, which means there can be no real cognitive equivalence between someone with mental retardation and a non-retarded person (Spitz, 1982). There is no point at which a person with low IQ will 'catch up' or reach adult levels of cognitive functioning.

The majority of studies have found that participants with mental retardation perform more poorly on most cognitive tasks even when matched for mental age with the control group. This phenomenon, termed 'mental-age lag' by Spitz (1982), supports the difference, or deficit, position. But a series of meta-analyses by Weiss and colleagues (1986) split the developmental view into two components: (a) cognitive stages defined within a Piagetian framework and (b) cognitive structures as defined by basic information-processing operations. This appoach implies that both the developmental and difference theorists are right. Children with mental retardation go through the same kinds of knowledge restructuring as described by Piaget, but do so more slowly than non-retarded children. But children and adults with mental retardation will always suffer a fundamental deficit in efficient (intelligent) information processing, even when compared with mental-age peers. So low IQ has a pervasive and enduring effect that is not ameliorated by progression through the stages of normal cognitive development.

Testing Detterman's theory

As Detterman (1987) has pointed out, it is a curiosity that while the study of mental retardation has a long history and has contributed to an understanding of intelligence in general, there have been few explanations of mental retardation in terms of contemporary theories. Those with retardation are regarded as simply deficient in whatever processes are hypothesized to contribute to intelligence.

Such theories as there are – for example, that people with mental retardation are specifically deficient in attentional processes (Zeaman & House, 1963) or laying down memory traces (Ellis, 1970) or in executive processes (Belmont & Butterfield, 1971) – have, in turn, lacked any real applicability to theories of intelligence in general.

So how does Detterman's theory fare in helping us to understand mental retardation?

To explain the phenomenon that individuals with mental retardation are poor on all cognitive tasks, Detterman (1987) has two theoretical options.

1. Because general intelligence is, by his definition, the average of all the independent component abilities, then chance alone would lead us to expect *savants* to be more common than they are.
2. But Detterman himself favours the second option, which is to suppose that some of the abilities are more commonly used than others. So while the basic abilities in Detterman's theory are independent of each other, he supposes that one or two of these abilities are more 'central' for all of us – i.e. involved in most higher-level abilities – and it is these 'central' abilities that are deficient in people with mental retardation.

Detterman accommodates both the developmental and difference positions by claiming that Zigler's developmental view applies to molar (or higher-level) measures. He argues that these are aggregate measures of the operation of the system as a whole. According to Detterman, Spitz's (1982) difference view, by contrast, applies to molecular (or low-level) measures. In this context, molecular measures would be measures of the basic cognitive abilities, each of which contributes to the functioning of the system.

While this neatly synthesizes the developmental and difference positions, it does prompt the question of why, on nearly all tests of basic abilities, not just a few central ones, groups with retardation perform more poorly than their mental-age-matched non-retarded peers. Indeed, it further prompts the question of how we can distinguish, in principle, between central abilities (i.e. those most deficient in people with mental retardation) and other basic abilities in a way that is not merely ad hoc.

Testing Anderson's theory

In Anderson's theory of the minimal cognitive architecture, the two causes of intelligence echo (to some extent) the pervasive view that there are two kinds of mental retardation.

The primary cause of mental retardation is deemed to be a slow basic processing mechanism (Anderson, 1986). This view implies that the majority of retarded individuals represent the tail of a statistical distribution of processing speed across the general population but these individuals will not necessarily have compromised modular functioning. For example, Moore, Hobson and Anderson (1995) and Anderson and Miller (1998) have shown that those with mental retardation may be as capable as anyone of executing the module-based, complex, perceptual processes underlying person perception and some aspects of object perception. In contrast, performance on simple perceptual discrimination that is required by a standard inspection time task is impaired in the group of individuals with mental retardation.

According to Anderson, a secondary hypothesized cause of mental retardation is where the absence of, or damage to, a module leads to a general cognitive deficit because of the module's central role in cognitive functioning. If representations (e.g. linguistic representations) are missing because of damage to a module, there will be striking patterns of cognitive breakdown in specific areas. But these deficits are not confined only to those areas where modules 'feed in' to a range of other cognitive skills. The clearest example of this is the association between mental retardation and autism (Anderson, 1998; Frith, 2003; Frith & Happé, 1998). It has been suggested that modular damage, specifically to the 'theory of mind' module (see chapter 9), may underlie specific cognitive deficits in autism (Baron-Cohen, Leslie & Frith, 1985; Frith, 1989; 2003; Leslie & Thais, 1992). A 'theory of mind' module would normally include representations like 'she wants' or 'he wishes', which are used to make inferences (i.e. to think) about social interactions. The absence of these kinds of representations not only makes any reasoning about human behaviour strikingly difficult, but, interestingly, it also seems to spill over to make most everyday problem solving extremely difficult and computationally expensive. It certainly results in low IQ scores.

Equally, Anderson's theory of the minimal cognitive architecture predicts that the normal apparatus underlying thoughtful processing might be spared in those with 'modular' deficits, in which case these individuals should show normal levels of speed of processing. This has recently been confirmed for performance on an inspection time task, where autistic participants were shown to have, if anything, superior levels of speed of processing (Scheuffgen et al., 2000).

As for the developmental versus difference views, Anderson argues that cognitive development is determined primarily by the acquisition of modules and that this accumulation will change the (Piagetian) cognitive stage of the child. Anderson suggests that modular functions are independent of IQ, so modules should be acquired according to the same developmental sequence in children with retardation as in other children. This could explain the finding from Weisz and colleagues that, in terms of Piagetian development, there is no deficit associated with mental retardation. But Anderson's theory of the mimimal cognitive architecture also accommodates the difference position. If the majority of children with mental retardation have slow speed of processing, this explains why they are still deficient in on-line processing (as measured, for example, by inspection time) compared with their non-retarded peers, even when matched for mental age.

Figure 13.6

Dustin Hoffman cleverly portrayed a character with *savant* syndrome in the movie *Rainman*.

SAVANT SYNDROME

Savants (formerly known as *idiots savants*) are individuals with measured IQ in the mentally retarded range who, nevertheless, display a single and exceptional cognitive ability.

For example, they might be able to calculate what day of the week any named calender date falls on (O'Connor & Hermelin, 1984). They might display high musical ability (Sloboda, Hermelin & O'Connor 1985) or artistic talent (Hermelin & O'Connor, 1990). Or they might be unusually skilled at learning foreign languages (Smith & Tsimpli, 1995) or factoring numbers (Hermelin & O'Connor, 1990). How are such feats possible if the general intelligence of these individuals is in the retarded range?

The memory explanation

An early view of *savant* skills was that they are based on an exceptionally good but essentially unorganized rote memory system and/or extensive practice (Hill, 1978; Horwitz et al., 1965). More recently, it has been suggested that many *savant* skills can be explained in terms of an extensive but generative (rather than passive) memory for domain relevant material (Nettelbeck, 1999; Nettelbeck & Young, 1996; Young & Nettelbeck, 1994).

There are some problems with the memory explanation of all *savant* abilities, though. O'Connor and Hermelin (1984, 1992), for example, found that calendrical calculators (those who can calculate what day a particular date falls on) can name days for dates for which no calender yet exists. They also use abstract rules and structures governing the calendar in order to perform their calculations (Hermelin & O'Connor, 1986). The memory explanation also seems an unlikely basis for artistic talent and for some other calculating abilities, such as the prime number calculating individual investigated by O'Connor and colleagues (Anderson, O'Connor & Hermelin, 1999; Hermelin & O'Connor, 1990). On the other hand, if *savants'* feats are accomplished using some kind of automatic or non-thoughtful processing (automatic long-term memory retrieval is the classic example of this), there is no inherent contradiction with the notion of *g*. However, it should be noted that there have even been suggestions of specific forms of memory deficits in autism (see Shalom, 2003, for a recent review).

Detterman (1996) does argue that *savants* falsify the idea that there is a single and common ability underlying all intellectual task performance. In so doing, Detterman takes a similar line to that advocated by Gardner (1983), namely that *savants* prove the fundamental independence of the component abilities that 'normally' make up *g*. Yet this feels just a little too easy. For one thing, the abilities that *savants* display are somewhat implausible candidates as the 'component abilities' of Detterman's theory. After all, *savant* skills represent rich, high-level abilities in themselves, not the basic procedures of information processing described by Detterman. Moreover, recent research with calendrical calculators has found that they are not talented mathematicians (although some have adequate mathematical ability), which challenges one of the main tenets for Gardner-like models of multiple intelligences (Cowan, O'Connor & Samella, 2003).

The modular explanation

Anderson's theory of the minimal cognitive architecture assumes that the brain damage that leads to *savant* syndrome has selectively spared some modules from the generalized brain damage that has led to mental retardation in these individuals. It is proposed that these modules come in three kinds:

Mark I modules are the full blown innate variety that most plausibly underlie *savant* talents in art, music and language. They are represented by all but one of the modules shown in figure 13.5.

Mark II modules are the fetch-and-carry mechanisms of cognitive processing, such as long-term memory retrieval, or the ability to recognize mental representations that forms the basis of the 'theory of mind' mechanism (Leslie, 1987).

Mark III modules are associative processes established after extensive practice, and they are not explicitly represented in figure 13.5.

According to Anderson, because *savant* abilities are modular there is no paradox in their existence in individuals with low IQ, which is a property of thoughtful processing. Frith (2003), Smith and Tsimpli (1995) and others have presented this model as the best fit for explaining observations of *savant* syndrome.

ENDURING ISSUES

Two enduring issues that have bedevilled research in intelligence are the genetics of IQ, and the relationship between race, genes and intelligence.

THE GENETICS OF IQ

Before considering whether intelligence 'runs in families' and, more specifically, how we can tell whether there is a genetic contribution to differences in IQ, it might be helpful to look at a few basic terms and methods from quantitative behavioural genetics – the discipline that aims to answer these questions.

Figure 13.7

Identical twins have identical genotypes, which makes them interesting participants for intelligence studies.

genotype our genetic complement, coded in DNA, that we inherit from our parents

phenotype the expression of our genes in behavioural traits that we can measure

Our *genotype* is the genetic complement, coded in DNA, that we inherit from our parents. No two people have identical genotypes except identical twins. The expression of those genes in behavioural traits that we can measure is called our *phenotype*. Phenotypes can vary because of genotypic differences and/or because the environment affects how our genes are expressed. IQ test scores are phenotypic measures, and intelligence is one of the most frequently researched traits in behavioural genetics simply because IQ represents one of the most reliable and important psychological measures.

Genetic contributions to IQ differences can be estimated by comparing the similarity of IQ in individuals of different degrees of genetic relatedness while also assessing environmental similarities and differences. Heritability is a statistic that represents the proportion of phenotypic variance that is due to genetic differences – that is, the extent to which differences in measured intelligence are due to genetic differences. The maximum possible heritability is 1.0 (100 per cent of the difference is inherited) and the minimum is 0 (none of the difference is due to genetic differences).

The influence of environment

The influence of the environment on phenotypes comes in two main forms. There are differences between families (levels of income, parental rearing style, number of books in the home, etc.) which make children raised in a particular home more similar to each other than to children reared in a different home. This source of differences is often called the effect of the *shared* *environment*. The second kind of environmental influence is differences within the same family (in birth-order, children's friends, school teachers, etc.). These effects make children in the same family different from each other and are referred to as *non-shared environment* effects.

We can measure the influence of the common, or shared, environment by comparing individuals who are reared together or apart. The extent to which pairs of individuals are more similar when they are brought up in the same home is a measure of the importance of the common or shared environment. For example, if the home environment makes a difference it should increase the similarity of, for example, identical twins when they are reared together compared with when they are reared apart (i.e. when they are adopted into different homes). Similarly, the extent to which siblings who are reared together in the same home but who are genetically unrelated (because one or both is adopted) are similar to each other gives an estimate of the influence of shared environment.

The effect of non-shared environmental variance can be detected in a number of ways. The most obvious is to measure the extent to which identical twins reared together (i.e. with both genetic and shared environmental variance in common) are different from each other due to the non-shared environmental influences they may experience when growing up (e.g. at school, or from peers).

Do we inherit our IQ?

Studies on the influence of genetic differences on intelligence are in broad agreement. Intelligence, as measured by IQ tests, has a substantial heritability.

Estimates of heritability vary between 80 per cent (Bouchard et al., 1990) and 50 per cent (Plomin 1990). So even the more conservative estimates argue that genetic differences are far from trivial – they are at least as important as environmental differences, and maybe more so. The Bouchard et al. (1990) study is particularly important because these researchers measured a number of variables that can potentially confound (see chapter 2) twin studies (such as the length of time the twins had been in contact with each other) and attempted to determine their influence on the estimate of heritability. It turns out that these effects are minor, contributing at most 3 per cent to the estimate of 70–80 per cent heritability in their study.

The many studies from the Colorado Adoption Project (see Plomin, 1990) estimate the heritability of intelligence at about 50 per cent. They suggest that the shared environment is more influential early in development than in later life (see figure 13.9). For example, the correlation between adopted children and their biologically unrelated siblings (who are usually reared from birth in the same family) averages around 0.2–0.3 before their teenage years.

Pioneer

Figure 13.8

Through his study of twins, Sir Cyril Burt concluded that intelligence is largely hereditary.

Sir Cyril Burt (1883–1971) encouraged new methodological rigour in data analysis through his use of factor analysis of complex data sets. He also contributed significantly to the development of intelligence testing methods, schools for children with intellectual disabilities, child guidance clinics, and the 11+ testing system in the UK in which all 11-year-olds were assessed for intellectual potential to provide optimal educational opportunities. However, it is probably for his analysis of twin IQs that he is best known. Burt compared twins raised together with those adopted out and concluded that intelligence is largely hereditary. In the latter part of his career, Burt was charged with falsifying data in his groundbreaking twin studies, but his findings have been supported by more recent research.

The importance of life events

Over the whole lifespan it seems that the most important environmental differences are those that are non-shared and unique to the individual concerned (that is, they are not shared by members of the same family). So rather than the major socio-economic variables (which represent a large part of the shared, or common, environmental variance) being the principal environmental contributor to difference in intelligence, it is unique life events that make up the major environmental contribution.

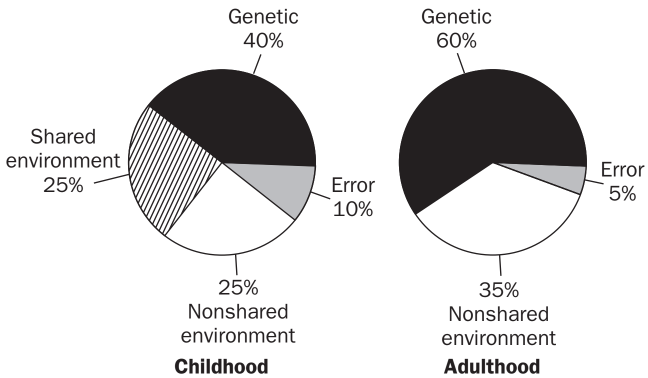

Figure 13.9

The proportion of variance in general intelligence accounted for by genes increases with development, while that accounted for by shared environment decreases. Source: Plomin et al. (1997).

In a review of adoption and twin studies, Scarr (1992) estimated that the contribution of the shared environment to differences in IQ is approximately zero by adulthood. This is consistent with the finding that the heritability of *g* increases throughout our lives (McGue et al., 1993), beginning at about 20–30 per cent in early childhood and increasing to about 50 per cent after adolescence (Bishop et al., 2003; Spinath et al., 2003). This may be explained by the increasing influence of the biological underpinning of intelligence across the lifespan, as the effect of the shared environment decreases.

All this means that, irrespective of our shared environment, most of us find ways ultimately to realize our genetic potential, depending on the effects of our idiosyncratic life events (i.e. non-shared environment).

Finding the IQ gene(s)

Most recently great excitement has surrounded the methodology of quantitative trait loci (QTL), which attempts to associate particular genes with specific behaviours. Researchers compare the DNA of a tightly defined group of individuals considered 'high' on some trait with the DNA of control individuals who, ideally, only differ by being 'low' on the same trait. In so doing, they hope to find genes that contribute to difference between the two groups.

This method has been successful at finding genes that appear to be associated with discrete pathological conditions, such as reading disorder (Cardon et al., 1994) and autism (Bailey et al., 1995). But the general consensus is that intelligence must be *polygenic*, which means that many genes contribute in an additive or dose-related fashion to IQ differences. If this is right, current QTL methods have very little chance of discovering the individual genes that each contribute only a relatively small proportion to the overall genetic effect. Even so, some researchers claim to have discovered a gene that is over-represented in individuals with a very high *g* (Chorney et al., 1998). While exciting, this methodology is new, and its results should be treated with caution.

Almost everyone now accepts that there are genetic influences on IQ differences, but the most important recent discoveries concern environmental rather than genetic influences, particularly the finding that it is the non-shared environment that has a lasting effect on individual intellectual differences. The challenge is to move on from the heritability issue to theories of how genetic predispositions may interact and correlate with environmental circumstances to produce the patterns of IQ differences that we find in our society (see Scarr, 1992).

Race, genes and intelligence

The issue of the genetic influence on intellectual functioning has historically gone hand in hand with the inflammatory issue of racial differences in intelligence. There is some conflict surrounding the term 'race' and whether, in fact, it is a scientifically valid entity. The term 'ethnicity' has been suggested as a more accurate alternative, but we use the term 'race' here to reflect more accurately the categorization used in the published research.

The race–IQ debate

In 1969, a famous article by Arthur Jensen provided a spark that re-lit the race–IQ debate. He commented that a much-lauded programme of early academic intervention for socially disadvantaged children, known as the Headstart Program, had not resulted in any increase in IQ, and that this was likely to be due to the genetic contribution to intelligence.

The idea that an important human trait like intelligence might be, in part, genetically determined and – worse – associated with racial characteristics spawned a stream of outrage, with claims of inherent white Caucasian racial superiority (see Gould, 1996, for a critical review). Such claims had been used in association with the availability of intelligence testing to support a discriminatory immigration policy in the United States in the early part of the twentieth century, favouring Anglo-Saxon immigrants over those of other nationalities on the (plainly ludicrous) grounds that the average IQs of the latter were in the feeble-minded range.

As recently as the 1970s, William Shockley, a Nobel laureate for physics (and therefore no expert in psychology), advocated a financial incentive scheme where individuals would be paid not to breed, the amount increasing as IQ decreased. Even more recently, Rushton (1997) has claimed evidence for genetically determined differences between races in many behavioural traits – intelligence being the most important.

And finally, publication of *The Bell Curve* (Herrnstein & Murray, 1994) reignited the fuse primed by Jensen's famous review. Not only did it claim overwhelming support for the idea that race differences in IQ are in part genetically determined, but it implied that nearly all social disadvantage of racial groups can be traced not to societal discrimination, but to inherited differences in IQ.

This issue is large and complex enough to warrant the many books and articles devoted to its discussion (for example, see Gould, 1996; Jensen, 1987; Rose, Lewontin & Kamin, 1984) and also to have evoked a strong and unprecedented public statement signed by 52 intelligence researchers in the *Wall Street Journal* in

December 1994, outlining what is known and what cannot reasonably be extrapolated from research on race and IQ.

The core of the race arguments rests on two major propositions, both of which we know are not true:

1. The reliably observed difference in mean IQ – amounting to one standard deviation – between black and white Americans is due to an inherent bias of IQ-type tests against minority groups (see figure 13.10). While some tests undoubtedly show some cultural bias, this is neither systematic nor large enough to account for these reliable IQ differences (see Herrnstein & Murray, 1994; Neisser et al., 1996). Most authorities now accept that the differences measured by IQ tests represent real differences in intellectual attainment. What is denied by most authorities in the field, however, is that these differences are genetic in origin. This brings us to the second untrue proposition.
2. Because we now know that individual differences in measured IQ have a large genetic component, it is probable that differences in IQ that may be observed between races are genetic in origin too (Herrnstein & Murray, 1994).

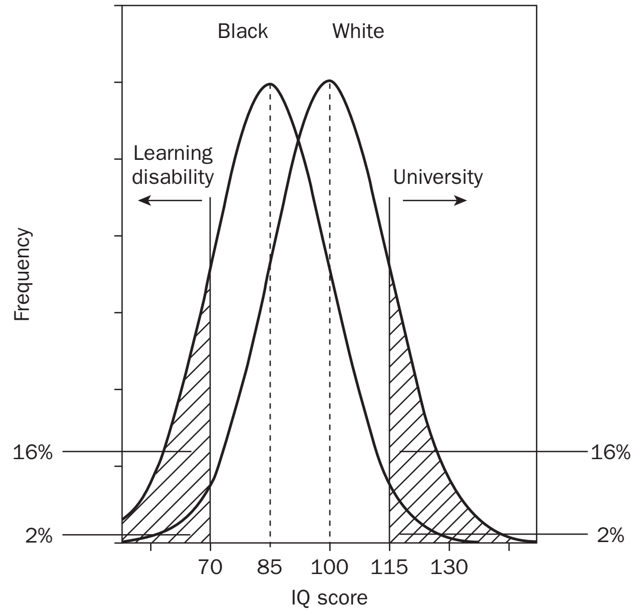

Figure 13.10

The consequence of one standard deviation difference in the mean of black and white populations for a set criterion based on IQ.

What we do know is that the heritability of within-population differences is logically independent of between-group differences in means (Block, 1995). So, for example, when wheat is planted in a field, some genetic strains will produce more than others under the same soil conditions. In other words, there will be individual differences in yield that are attributable to genetic differences between strains of wheat. On the other hand, the average level of production is likely to be very different in different fields – and this is attributable to the large influence of the different soils (environment) in the fields. So the difference between group means (average wheat yields in each field) and the cause of the within-group individual differences (differences between the genetic strains in each field) are logically distinct.

To bring this back to people, what this means is that we cannot necessarily infer that reliable differences between human groups ('yield of wheat in different fields') are due to similar mechanisms that determine differences within groups ('yield of

Everyday Psychology

Intelligence tests

Intelligence tests are widely used for a range of purposes, but what can they tell us? In 1994, the American Psychological Association Task Force on Intelligence summarized their findings on this subject in a review of research. They found that intelligence test performance correlates with school grades at about 0.50, total years of education about 0.55 and supervisor ratings of job performance between 0.30 and 0.50. This means that intelligence test performance is one of the best predictors we have of academic and work-related performance (Schmidt & Hunter, 1998).

On the other hand, the modest magnitude of these correlations suggests that other factors – such as personality and socio-economic status – also significantly contribute to these outcomes. Indeed a correlation was found between IQ and socio-economic status of about 0.33.

In addition to educational and vocational uses, intelligence tests form an important part of neuropsychological assessment for people with suspected brain injury, tumours or disease (such as dementia) (Lezak, 1995).

The Wechsler tests are now probably the most widely used individual tests of intelligence and have impressive reliability and validity. They include the WAIS (Wechsler Adult Intelligence Scale), the WISC (Wechsler Intelligence Scale for Children) and the WPPSI (the Wechsler Preschool and Primary Scale of Intelligence) – each devised very much in the spirit of the Binet scales. The tests are divided into performance and verbal subscales, and the resulting scores can be used to compute three intelligence quotients, or IQs – verbal, performance, and full scale (which is derived from combining the verbal and performance scores).

The verbal subscales, as their name suggests, usually require a verbal response and test verbal knowledge. Examples include:

- tests of vocabulary;
- general information, or common world knowledge (e.g. 'In which direction does the sun rise?');
- comprehension about problem solving in daily life situations (e.g. 'What would you do if . . . ?');
- ability to draw out similarities between objects or ideas (e.g. 'In what way are a dog and a cat alike?'); and
- ability to recall strings of numbers and/or letters.

The performance subscales do not require a verbal response. Instead they usually require the testee to manipulate pictures, objects and non-verbal symbols. Non-verbal tests are considered to be more 'culture-free' than other intelligence tests as they do not depend on language or culturally embedded knowledge (though it should be noted that no test can be completely 'culture-free').

The performance tests include:

- block design, in which red and white cube-shaped blocks must be arranged to match a pattern shown to the testee (see figure 13.11);
- matrix reasoning, in which a series of figures is presented and a missing figure must be identified from a set of alternatives (see figure 13.12);
- digit symbol, in which a list of arbitrary symbols must be replaced by their corresponding numbers under speeded conditions;
- picture completion, in which a missing part of a picture must be indicated;
- picture arrangement, in which a series of pictures must be arranged in an order that generates a coherent narrative; and
- object assembly – essentially a jigsaw puzzle involving familiar objects.

A major difference between the Wechsler tests and Binet's intelligence tests is the way in which IQ is calculated. The Binet tests typically calculated an IQ after first calculating a mental age (see page 272). The Wechsler scales, by contrast, calculate a deviation IQ directly from age norms – that is, IQ reflects the position in the distribution of scores obtained from a standardization sample of people of the same age.

Schmidt, F.L., & Hunter, J.E., 1998, 'The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings', *Psychological Bulletin*, 124, 262–74.

Figure 13.11

The Block Design subtest from the WISC does not require a verbal response. Red and white blocks must be arranged in a particular pattern.

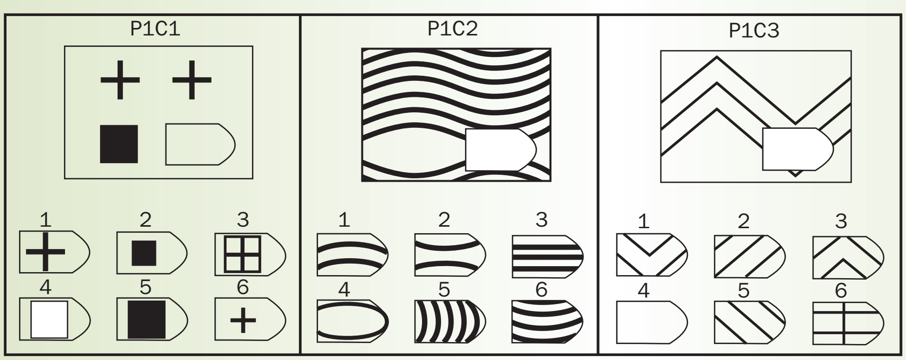

Figure 13.12

Example of a Matrices type item. The item that completes the pattern must be chosen from one of the six options.

wheat in the same field'). It is perfectly plausible, for instance, that differences in IQ between races are due to differences in the typical environment ('fields') across these races.

Explanations for the false correlation

Why is a genetic explanation usually cited by the proponents of racial differences in intelligence, rather than the more obvious environmental explanation (such as the different socio-economic circumstances of the two groups)? The likely reason is the association of group membership with a strong genetic marker – in this case skin colour.

To illustrate this point in another way, imagine a fictitious land governed by a dictator who wants a class of workers to perform the more menial roles in society. This dictator introduces the 'regime of the hammer', whereby every child with red hair (which, for the sake of this argument, we will presume is a highly heritable trait, just like black versus white skin colour) is tapped on the head with a hammer in a way that lowers their IQ by one standard deviation. This leads to an over-representation of red-haired people with lower IQ. The effect of such a heinous act on the population heritability of IQ (as calculated in a computer simulation) is shown in table 13.1.

The data show that, as desired by our dictator, red-haired people now have a lower mean IQ than people who do not have red hair. Yet the heritability of IQ in the whole population has only been reduced from an extremely high 80 per cent to a still very high 74 per cent by the hammer regime. This highlights two points:

Table 13.1 IQs of population and red-haired children before and after the hammer regime.

	Before hammer	*After hammer*
IQ mean	100.05	98.55
SD	15.01	15.65
Heritability	79.9%	74%
Red hair		
IQ mean		85.24
SD		15.17

1. The lower IQ of red-haired people is environmentally caused (by a hammer blow), even though it is correlated with a genetic difference. (Genetic differences lead to differences in hair colour, and it is the genes for red hair that lead to the environmental insult.) Because the genetic differences associated with hair colour are so compelling, it is likely that a genetic cause for the differences in intelligence will be seized upon and used to explain the lower IQ of people with red hair.
2. The environmental cause of the lower IQ of red-haired people is consistent with a high heritability for differences in the population as a whole. The analogy with black/white differences in American data should be obvious. If being black means a lifetime of disadvantage and different treatment, this environmental effect could cause a difference in group means in IQ (just like being hit on the head with a hammer) that is perfectly consistent with the idea that differences in general have a high heritability.

In case you are still finding it difficult to imagine environmental or cultural differences causing a difference as large as one standard deviation (the reliable race-related IQ difference) in the face of a high heritability for IQ, consider the 'Flynn effect'. Flynn (1987) has shown that there has been a standard deviation increase, per generation, in the mean level of intelligence test performance for most of this century in Western society, which equates to about three IQ points per decade. Such a difference has to be the result of an environmental change, because gene frequencies in populations could not change so quickly. If there can be shifts of one standard deviation in IQ between generations that are environmental in origin, despite the high heritability of IQ differences, why could there not be similar environmentally mediated differences between populations within the current generation?

FINAL THOUGHTS

Given recent progress in our understanding of the concept of intelligence, it is little wonder that we are on the brink of a new understanding of the interplay between genes and environment in shaping intelligence. Undoubtedly, great progress will be made in this area over the next few years. Perhaps some of you will be driving that process.

The question of the mechanisms underlying individual differences in intelligence is one of the oldest topics in psychology. This question has spawned not only a great deal of research but enormous controversy, which has been detrimental to the development of the science of intelligence. While this controversy is unlikely to go away, it now seems that, after some years of stagnation, the field is at last moving forward. New ideas for reformulating old problems and a greater understanding of the theoretical issues should lead to advances in our scientific understanding, and in the consequences of our knowledge for social issues. This is an exciting time to be involved in research on intelligence.

It is perhaps worth remembering another important finding from the research, that is that intelligence is not related to happiness (Kammann et al., 1979; Sigelman, 1981; Wilson, 1967). There is even evidence to suggest that genius is often associated with emotional turmoil and psychopathology (Albert, 1983). Nor should intelligence be placed above, focused upon more intensively, or valued more greatly than other aspects of human ability in deciding on social policy. Psychologists traditionally involved in the study of individual differences have attempted to understand the complexities of human lives, needs and behaviours by considering the interplay between individual differences in a range of areas. These have included intellect, personality, physical attributes and opportunity. Each of these factors has been found to influence life achievement and performance significantly. Unfortunately, over recent years the field has become somewhat splintered, and the study of such multidimensional interrelationships is the exception rather than the rule. But perhaps (and hopefully) this is the direction of the future.

Summary

- The central discovery of research on intelligence is the existence of an attribute that we can call general intelligence.
- Spearman has been vindicated by modern research, particularly the finding that general intelligence may be related to a property of the brain that we can best summarize as speed of information processing.
- However, there is more to intelligence than Spearman's *g*, and in this sense the spirit of Thurstone, too, has been vindicated. Various theories accommodate the relationship between general intelligence and more specific abilities differently, but they have in common the ability to generate new insights in a number of areas, including the nature of mental retardation and the savant syndrome.
- Despite the fact that the upper limits of our intellectual potential are constrained by our biology, the development of our intelligence can be importantly facilitated by the richness of the environment provided by our families in our early years and by aspects of our experience outside of our families as we get older. Intelligence can be significantly compromised under conditions of extreme deprivation.
- The differences in measured IQ between races is most likely attributed to pervasive differences in environmental (life) circumstances of the groups.
- In any population, there will be a large number of people of average intelligence, very few of extremely low IQ and an equal paucity of people with very high IQ. This is called a normal distribution.
- We all go through stages of cognitive development as we get older. This affects certain aspects of our measured IQ (such as the degree to which we are able to think abstractly) but not others (such as the speed at which we process information.)
- Life performance and achievement is partly a function of intellectual capacity but is also significantly influenced by personality and other individual characteristics.

REVISION QUESTIONS

1. How have intelligence tests helped or hindered our quest to understand intelligence?
2. Are people with savant syndrome 'intelligent'?
3. Is genius just a matter of high IQ?
4. How important is intelligence as a defining characteristic of a person?
5. How likely do you think it is that we will find genes for intelligence?
6. Do all people with an IQ of 100 function equally well in their life?
7. Can someone 'catch up' intellectually if they have experienced deprivation in their first few years of life?
8. If you move to live in another culture that is unfamiliar to you, does your intelligence 'drop'?

Further Reading

Anderson, M. (ed.) (1999). *The Development of Intelligence*. Hove: Psychology Press.
A contemporary account of current theories on the development of intelligence by experts in the field.

Deary, I.J. (2001). *Intelligence: A Very Short Introduction*. Oxford: Oxford University Press.
A very readable and clear introduction to the main issues.

Gardner, H., Kornhaber, M.L., & Wake, W.K. (1996). *Intelligence: Multiple Perspectives*. Fort Worth, TX: Harcourt Brace.
A series of alternative accounts of intelligence, particularly multiple intelligences theory.

Jensen, A.R. (1998). *The g Factor: The Science of Mental Ability*. Westport, CT: Praeger Press.
A highly technical read, but the definitive scientific account of general intelligence.

Mackintosh, N.J. (1998). *IQ and Human Intelligence*. Oxford: Oxford University Press.
A very considered and scholarly review of the field.

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