Behavioral Genetics 7

Key Terms

allele
assortative mating
behavioral genetics
Flynn effect
genome
genotype
heritability estimate (HE)
molecular genetics
multivariate genetic analysis
phenotype

Chapter Outline

7.1 INTRODUCTION

In chapters 5 and 6, I examined theories and findings on intelligence or cognitive ability that attempt to describe, measure, and compare individuals on the basis of their ability to carry out mental operations, learn new things, and acquire knowledge. More than 100 years after Spearman's (1904) benchmark publication on the *g* factor of psychometric intelligence (see section 5.3.4), intelligence is a consolidated psychological construct. There are now many reliable psychometric tools to predict academic and occupational achievement, as well as a wide range of other variables of psychological, economic, and political importance, that possess a great degree of accuracy.

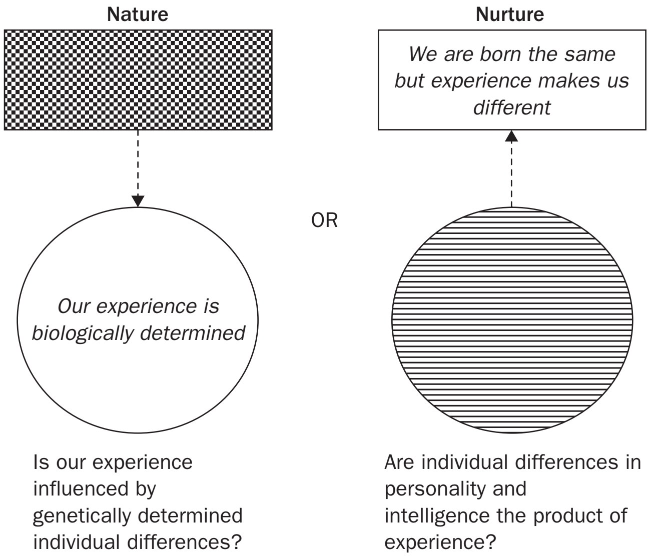


Figure 7.1 Individual differences: genetically or environmentally determined?

But the fact that some people score higher on IQ tests than others and that IQ tests are good predictors of performance does not really answer the fundamental question of *why some individuals are brighter than others*. Likewise, knowing whether someone is more or less neurotic, extraverted, or open to experience does not tell us about the causes of these differences, although, as seen, Eysenck and Gray hypothesized biological causes for such differences (see sections 2.8 and 2.9, respectively).

In recent years, differential psychologists have invested considerable time and effort to assess the extent to which individual differences may be inherited. The most successful and influential of these approaches is represented by the field of **behavioral genetics**, which is concerned with the assessment of the *biological* (genetic) and *environmental* (non-genetic) causes of intellectual ability and personality traits. Behavior genetics represents an area of overlap between genetics and behavioral sciences. Accordingly (see Figure 7.1), it attempts to provide an estimate of the extent to which individual differences, notably personality and intelligence, may be understood as the product of experience (e.g., learning, education, acquired values, nurture) or "genetically in-printed" information.

behavioral genetics study of the biological basis of individual differences; it identifies genetic (biological) vs. non-genetic (e.g., environmental) causes of behavior, typically whether nature or nurture plays a larger role in determining individual differences in personality and intelligence

7.2 EARLY FOUNDATIONS OF BEHAVIOR GENETICS

Although the study of the genetic and environmental causes of intelligence has recently become a "fashionable" research area, it is by no means new. Since the very beginning of intelligence research, psychologists have attempted to assess the impact of *nature* and *nurture* on individual differences. Very often these attempts have been interpreted in a political rather than scientific light, such that ideological views have influenced several eminent IQ researchers to either embrace or reject biological conceptions of intelligence.

However, a fair evaluation of early theories on personality and intelligence will indicate that, although most pioneers in this area believed that individual differences in intellectual ability and personality were largely inherited or *innate* (i.e., caused by biological factors), they were also aware of the effects of the environment (e.g., upbringing, rearing, education) on individuals' level of intelligence and personality traits. In most cases, though, it was the emphasis on the former that sparked off controversies and debate.

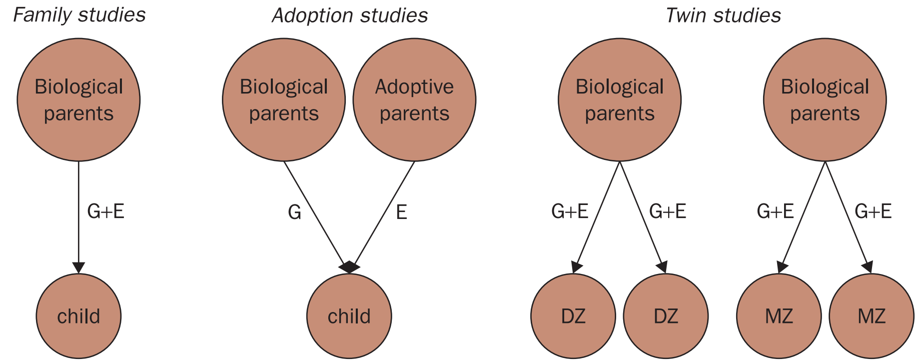
Francis Galton was the first to speculate about the contribution of genetic and environmental factors to intelligence (see section 5.3.1 and Box 5.1). His conclusion that "nature prevails enormously over nurture" (Galton, 1883/1907/1973, p. 241) set a paradigmatic trend in differential psychology, inspiring leading figures in the field even today. Although the first twin studies were not conducted until the mid-1920s (e.g., Theis, 1924), it was Galton (1876) who conceived this type of research design. Twin studies are an extremely powerful tool to reveal the genetic roots of a trait or **phenotype** in a specific population. Unlike family studies, which "confound" or mix environmental and genetic influences, twin studies, particularly those comparing identical or monozygotic (MZ) with non-identical or dizygotic (DZ) twins, provide an accurate estimate of the variance accounted for by biological factors on one hand, and by environmental factors on the other (see Figure 7.2).

phenotype the expression of an individual's genes in behavioral traits that can be measured

In statistical terms, indicators of genetic influences are represented by the so-called **heritability estimate** (HE). For instance the HE of intellectual ability ranges from .50 to .70, which implies that 50 to 70 percent of the variance in IQ can be explained by genetic differences. Thus HEs indicate what proportion of the total variance can be attributed to genetic variation.

heritability estimate (HE) a statistical indicator of the influence of genetic factors on individual differences in behavioral traits, showing what proportion of the total variance is attributable to genetic variation

In the early 1960s, a widely quoted article published in the prestigious journal *Science* reported the first systematic evidence, derived from twin and adoption studies, for the hereditary nature of intelligence (Erlenmeyer-Kimling & Jarvik, 1963). As differential psychologists had hypothesized for many years, genes were shown to have a strong influence on individual differences in cognitive ability. During this same period, unprecedented discoveries in biology, notably the structure of DNA, provided a robust scientific backup for psychology's new vision of differential psychology. But what is DNA, and what is its importance with regard to individual differences?



Child shares genes (G) and environment (E) with parents. The effects of genes and environment are thus confounded.

Child shares genes with biological, environment with adoptive, parents. Genetic effects are evident if child behaves like the biological parents, and vice versa.

Fraternal/dizygotic (DZ) twins share 50% of their genes, whilst identical/monozygotic (MZ) twins share 100% of their genes. Comparing MZ and DZ twins will provide evidence for the effect of genes (as in matched designs).

Figure 7.2 Family, adoption, and twin designs.

7.3 DNA: SOME BACKGROUND

DNA stands for *deoxyribonucleic acid* and represents a long formation or chain of acids called "nucleotides," which are in turn made of:

a) *deoxyribose* (i.e., a pentose, that is, a 5-carbon sugar);
b) *phosphoric acid* (i.e., a mineral acid represented by the chemical formula H_3PO_4);
c) *organic/nitrogenous bases* (i.e., *purines* – "adenine" and "guanine," or *pyrimidines* – "cytosine" and "thymine").

The most important characteristic of DNA is that it remains unchanged throughout the lifespan and is transmitted intact to subsequent generations. In some cases genetic mutations may take place that may affect it, but only over millions of years. Whereas behavior may have an impact on neurotransmitters and cause physiological changes in the brain (for example, at this moment your brain is transcribing genes to create neurotransmitters and synthesize the information you're reading), DNA cannot be influenced by behavior. This has made DNA the most important correlate of behavioral outcomes, as it is always *causal* in nature. Thus individual differences at the DNA or **genotype** level can always be expected to cause individual differences at the trait or *phenotype* level, and not vice versa.

genotype the genetic complement, coded in DNA, that individuals inherit from their parents. Only identical twins have identical genotypes

Almost half a century after the discovery of DNA (in 1953), scientists have been able to provide a "working map" of the genetic constitution of human beings, including a detailed description of DNA (see Figure 7.3 for a graphical depiction of DNA). These findings were unveiled by the *Human Genome Project* in 2001. Although there are far fewer human genes than we thought in the past (originally the number was estimated at 100,000, whilst the correct number is unlikely to exceed 30,000 by far), there are 3 billion DNA letters in the human **genome**!

Table 7.1 DNA at a glance

DNA stands for *deoxyribonucleic acid*.	It is composed of *adenine*, *guanine*, *cytosine*, and *thymine*.
It is a long chain of acids (*nucleotides*).	There are 3 billion letters of DNA in the *human genome*.
It is shaped as a *double helix*.	These nucleotide bases are "steps" in the double helix staircase of the DNA.
It was discovered in 1953.	"Genes" are transformations of DNA into *ribonucleic acid* (RNA) and amino acids.
The genetic code was discovered in 1966.	Since 2001, the estimated number of human genes is approximately *30,000*.

genome the full complement of genetic information, including the set of chromosomes and the genes they carry, inherited by an individual organism from its parents

One of the most significant scientific discoveries is that there are only minor structural differences between the DNA of human beings and that of other mammals. Thus very *subtle* variations in DNA are enough to determine the differences between one species and another (Brett, Pospisil,

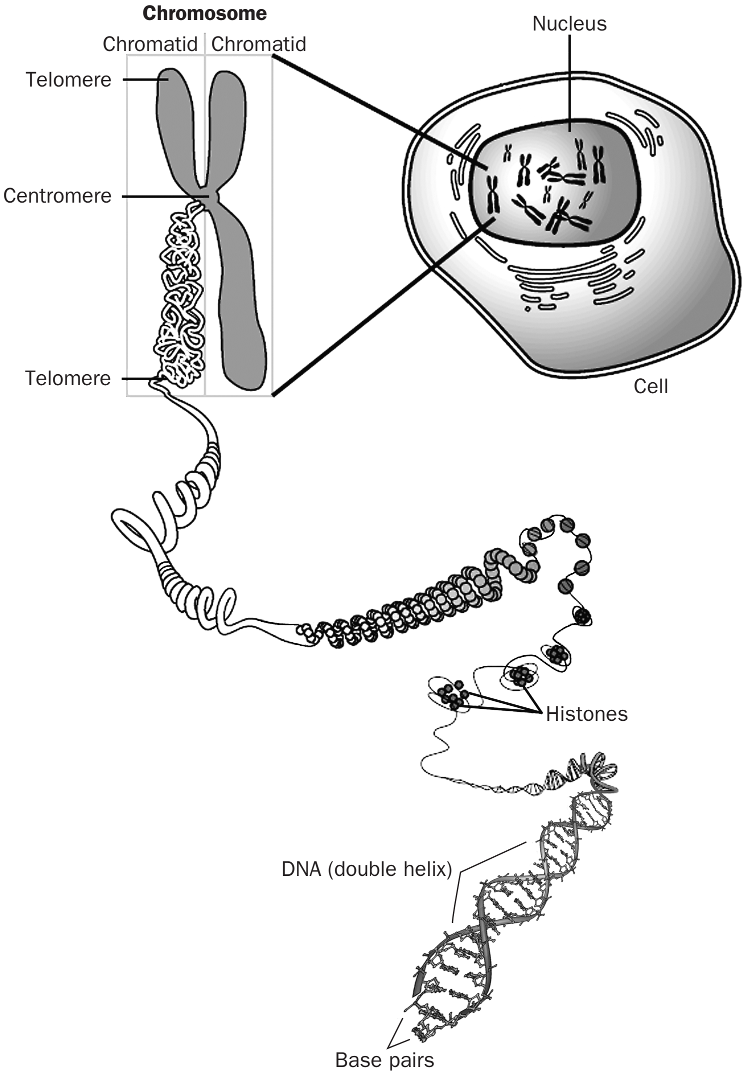


Figure 7.3 Cell, chromosome, and DNA.
Source: www.accessexcellenceorg/AB/GG/chromosome.html.

Valcarcel, Reich, & Bork, 2002), even between men and mice! The implications for the study of individual differences cannot be underestimated. If there is only a marginal difference between the genetic make-up of humans and other species, such that, for example, humans and chimpanzees may share 98 percent of their genes, imagine how subtle genetic differences between two individuals would be, let alone if we compare their IQs.

Indeed, differences between two members of the same species are still unobservable at the level of the DNA. Most of the biological letters (*A*, *C*, *G*, *T*) composing the DNA sequence are the same for all humans, and many of them are even present in insects. Given the fast advances in genetic research, particularly in the area of molecular genetics, it is not unrealistic to expect that, sooner or later, behavior-genetic research *will* be able to accurately map individual differences onto specific DNA sequences, in order to compare one human genome with another.

7.4 THE POWER OF GENES: RECENT EVIDENCE FOR THE HERITABILITY OF INTELLIGENCE

Recent studies have provided compelling evidence for the biological roots of cognitive ability. Although most studies conceptualize cognitive ability in terms of the general intelligence factor *g*, thus undermining heritability differences at the level of specific abilities, the data indicate that about 50 percent of the total variance in *g* can be attributed to DNA differences between individuals. Although this percentage may suggest that "only" half of the variance in intelligence is of a genetic nature, implying that the "other half" must be due to environmental or nurture differences, the real impact of biological factors may be higher than 50 percent, especially because of confounded errors of

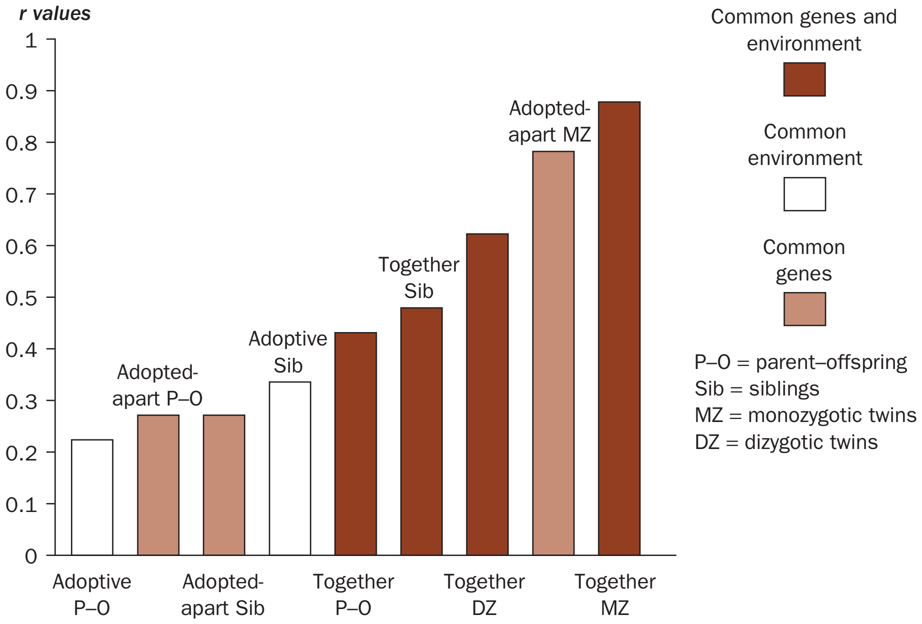


Figure 7.4 IQ correlations for family, adoption, and twin designs.
Source: Adapted from Plomin & Spinath (2004).

measurement. Several non-ability factors such as anxiety or motivation may slightly distort the accuracy of IQ tests as measures of cognitive ability, moderating the relationship between "actual" intelligence and IQ test performance. This means correlations between ability measures and other criteria should be "corrected for attenuation" (see section 5.3.4). When this is done, genes tend to account for more than half of the variance in intellectual ability.

Figure 7.4 summarizes the average IQ correlations between different family members, including both adoption and twin studies. As shown, the lowest IQ correlations are found between adoptive parents and their offspring, with an average *r* value close to .02. At the other end of the spectrum, we find correlations as high as *r* = .85 between MZ twins who grow up together. If you think that the "test-retest" correlation of (good) IQ tests is rarely higher than .90 (indicating there is some variability within individuals' IQ test performance, such that they do not always obtain exactly the same score), the correlation between MZs' IQ scores is no doubt substantial.

In order to control for confounding effects of both environment and genes, it is important to examine data from adopted-apart twins (i.e., twins who were separated shortly after birth and grew up in different families, thus lacking a shared environment) and adoptive children. In Figure 7.4, the IQ scores of adopted-apart MZ twins tend to be very similar (approximate average *r* = .76), whilst adopted-apart siblings (who share half the number of genes than MZ twins) are only vaguely similar in their IQs (*r* = .24). In fact, IQ correlations are much higher in adopted-apart MZ twins than adoptive siblings (*r* = .33) and adoptive parent–offspring pairs (*r* = .20) growing up together. Another interesting finding refers to the differences in IQ correlations between DZ and MZ twins brought up together: the correlation for MZ twins is almost 30 percent higher than that for their DZ counterparts.

Overall, the pattern of results summarized in Plomin and Spinath's (2004) review illustrates quite clearly that there are strong genetic effects on intellectual ability, such that *the level of genetic relatedness is positively and significantly associated with the size of IQ correlation between family members*. At the same time, there are some environmental effects on IQ, too, such that shared environment (common upbringing) is also a positive predictor of similar IQ scores, though weaker than genes. This means that people are more likely to have similar levels of intelligence if they have more genes in common (e.g., MZ twins share *all* genetic information as they develop from the same egg) and have been brought up in the same environment. It is no wonder, then, that both views on the causes of intellectual ability, namely environmentalist and biological, have found empirical support for their theories.

The debate around the determinants of intellectual ability has generated as much lay curiosity as academic research, and during the past 20 years intelligence has been the target of substantial behavior-genetic research. Thus, the results depicted in Figure 7.4 have been replicated cross-culturally, for instance in Russia, Germany, India, and Japan. Only personality traits have received comparable attention because of the relative straightforwardness of obtaining self-report data.

7.5 INTELLIGENCE AND ASSORTATIVE MATING

Birds of a feather flock together.

assortative mating the selection of a partner who possesses similar genetic characteristics, such as height, color of eyes, and cognitive ability

One important aspect to determine the heritability of any trait (physical or psychological) is **assortative mating**, which consists in the non-random selection of a partner of similar genetic characteristics, such as height, color of eyes, and cognitive ability. If consistent, the procedure of assortative mating may result in the *evolution* of the species by "improving" the genes in a way that favors competition and adaptation. For example, our eyes or our stomach may have developed into a more "efficient" or adaptable organ throughout time, and the same type of evolution may have affected the brain. Thus sociobiologists have long argued that the basic evolutionary goals are common to both human and non-human animals: finding and harvesting resources, avoiding predators and illness, and reproducing ("spreading the seeds" in the case of males, and looking for a male who can "protect their offspring" in the case of females) are universal instinctual objectives.

There is, therefore, an important evolutionary component underlying assortative mating, especially when it comes to intellectual ability, as the offspring of brighter parents will inherit more "intelligent" genes. Moreover, to the extent that partners with lower IQs tend to have significantly more children than their higher-IQ counterparts, assortative mating will affect the distribution of IQ scores (though this idea is inconsistent with evidence for the generational increases of IQ scores; see section 7.12 on the "Flynn effect"). There is a substantial level of assortative mating with regard to intellectual ability, much larger (about twice as much) than for weight, height, and even personality traits. Thus the typical correlation between partners' IQ is $r = .40$, whilst for weight, color of skin, or personality variables it rarely exceeds $r = .20$.

Another reason for the importance of assortative mating in behavior-genetic research is that it *increases* the variance attributed to genetic factors, causing IQ correlations between family members to increase generation after generation. This leads to a growing longitudinal tendency for partners to become more homogeneous or alike and for genetic differences between them to be reduced. If this logic is applied to our interpretation of behavior-genetic studies (i.e., adoptive, family, and twin designs), we will realize that the effects of assortative mating are different for DZ than MZ twins, and that IQ correlations for the former are *inflated* by non-random processes of selection that take into account observable psychological traits such as intelligence. Thus although DZ twins are not as closely related genetically as MZ twins (who share *all* genetic information), the genetic differences between the former have been progressively reduced through assortative mating.

7.6 THE IMPORTANCE OF THE ENVIRONMENT

Any objective and non-biased reading of behavior-genetic research will lead you to conclude that the debate between environmentalists and geneticists is fed by ideological rather than empirical motives. Within the scientific community, differential psychologists have long stopped arguing about the question of whether biological or educational factors lead to individual differences in intellectual ability, as there is longstanding evidence for the effects of both. The compelling evidence for the power of genes has not really undermined the environmentalist argument. Rather, the paramount achievements of genetic research to provide an accurate estimate of the impact of biological factors on individual differences in personality and intellectual ability have made an equally important contribution to demonstrating the effects of non-genetic factors.

As noted, twin studies provide indirect evidence for the effect of environmental or non-genetic factors on intelligence, because not all variance can be explained by genetic factors. That said, it may be exaggerated to conclude that because 50 or 60 percent of the variance in intelligence is explained by genes, the remaining 50 or 40 percent is due to "nurture variables" such as upbringing, education, and imitation. Instead, a more accurate estimate would include error variance in the equation and bear in mind that it would be unrealistic to explain 100 percent of the variance anyway, simply because our measures are not perfect. On the other hand, more direct evidence for the effects of environmental variables on individual difference traits can be obtained from studies on adoptive children and parents (see again Figure 7.4). Although there are non-genetic influences on personality and intelligence, these seem to be substantially smaller than genetic ones.

Plomin and Spinath (2004) noticed that "because adoptive siblings are unrelated genetically, what makes them similar is shared rearing, suggesting that about a third of the total variance can be explained by shared environmental influences" (p. 114). However, differential psychologists have yet to identify the *specific* environmental factors that may cause individual differences (and similarities) between individuals. Apart from general environmental factors such as socioeconomic status or level of education, few influential factors have been specified.

On the other hand, whilst nurture has clear developmental effects on intellectual ability and skills acquisition, the importance of upbringing – as opposed to genes – declines after adolescence. Conversely, the effect of genes tends to *increase* over time, leading to higher IQ correlations between genetically related individuals after adulthood. Accordingly, and somewhat counterintuitively, genes have longstanding effects on behavior and are expressed longitudinally in a way that prevails over environmental factors.

However, it is difficult to "break down" the variance into biological and environmental factors because genes play an active role in "selecting, modifying, and creating our own environments" (Plomin & Spinath, 2004, p. 114) (see sections 7.7 and 7.10 for a discussion of this point). Thus even adoption studies, which are supposedly aimed at testing the effects of nurture, may confound genetic sources of variability.

7.7 BIOLOGICAL EFFECTS ON INTELLIGENCE: WHY DO THEY INCREASE ACROSS THE LIFESPAN?

The consistent finding that genetic correlations for IQ tend to increase as individuals grow older is as surprising as it is enigmatic. Given that environmental influences on intelligence can only act on experience and would logically undermine the effect of genes, one would expect the opposite pattern of results to occur. How, then, can these findings be explained?

Two different methodologies have been employed to test the longitudinal effects of genes on intellectual ability. The first compares MZ and DZ twins across the lifespan and indicates that IQ correlations for DZ twins tend to *decrease* over time, notably after adolescence, whilst IQ correlations for MZ twins remain relatively stable until adolescence but continue to *rise* after that (up to $r = .86$ more or less). This pattern of results (shown in Figure 7.5) suggests that environmental influences on IQ do *not* undermine the effects of genes, especially when there is high genetic concordance between siblings, such as in the case of MZ twins.

A second type of design has aimed to identify changes across the lifespan in the correlation between IQ scores of biological parents and their children when the children have been given away for adoption. These correlations have also been compared with those between adoptive parents and children (that is, non-genetically related parent–offspring pairs), as well as control groups. These types of design can provide a relatively direct estimate of heritability as they indicate that:

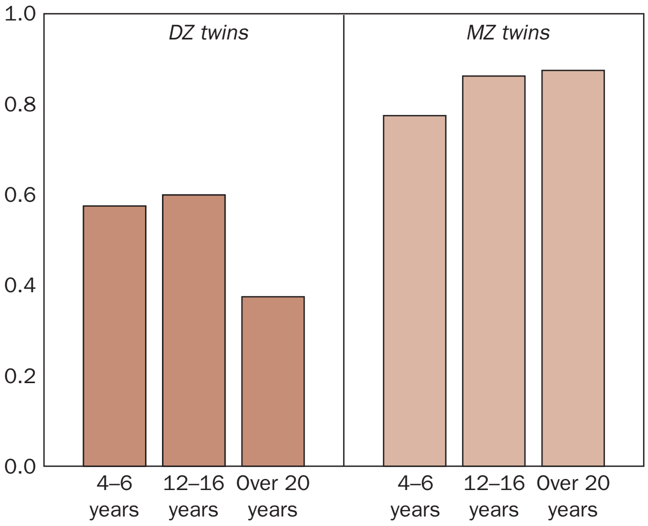


Figure 7.5 DZ and MZ IQ correlations across age.
Source: Adapted from McGue, Bouchard, Iacono, & Lykken (1993).

a) IQ correlations between biological or "original" parents and their adopted-away or original children are similar in size to that of control groups, i.e., biological parents living with their children rather than giving them away for adoption. In simple terms, children's intelligence resembles that of their biological parents, regardless of whether they grew up together or not.
b) IQ correlations were higher in control groups and biological-adopted-away pairs than in adoptive-adopted pairs. This means that the resemblance between the IQ scores of adopted-away children and that of their original parents was larger than the one between adoptive parents and their adoptive children.
c) Adoptive parents show very little resemblance to their adopted children when it comes to IQ scores.

It seems that IQ-related genes may *activate* only in late childhood or adolescence, such that "relatively small genetic effects early in life snowball during development, creating larger and larger phenotypic effects as individuals select or create environments that foster their genetic propensities" (Plomin & Spinath, 2004, p. 114). Interestingly, this hypothesis is supported not only by the higher IQ correlations between biological parent–children pairs than adoptive parent–children pairs but also in developmental studies that follow up adoptive siblings as they grow older.

Longitudinal adoption designs, such as McGue et al. (1993), indicate that correlations between adopted siblings tend to drop considerably after childhood, implying that, as individuals grow older, the effects of shared environment on IQ tend to decrease. This is consistent with the incremental effects of genes or biological factors on IQ scores: simply said, genes tend to matter more and more as one grows older, whilst the opposite is true for shared environment. One hypothesis to explain such a pattern of results is that genes "build up" novel cognitive functions leading to higher-order, more sophisticated reasoning processes. On the other hand, the decreasing effects of environmental factors on IQ may be explained by *change* in environmental variables like socioeconomic status and education: until late adolescence, siblings are likely to have similar levels of income and education, but after that differences between them are likely to appear.

It is noteworthy that behavioral-genetic studies have not always examined the same type of abilities or aspects of intelligence. In fact most studies of this sort have conceptualized cognitive ability in terms of psychometric *g* (see section 5.3.4 on Spearman). This has implications because different abilities may develop at different stages and, moreover, be more or less affected by learning and education. For example, Cattell's distinction between *gf* (fluid intelligence) and *gc* (crystallized intelligence) (see section 5.4) implies that certain aspects of cognitive ability have a strong biological component, whereas others are more exposed to environmental influences (e.g., education, learning, intellectual investment).

Like *gf*, the general intelligence factor is largely biological and "culture free," which means there is little reason to expect non-genetic influences when intelligence is conceptualized in terms of psychometric *g*, a fact acknowledged by leading behavior-genetic researchers. For example, Plomin and Spinath (2004) noted that "attempts to find genes for specific cognitive abilities independently of general cognitive ability are unlikely to succeed because what is common among cognitive abilities is largely genetic and what is independent is largely environmental" (p. 116). Even fluid abilities such as spatial intelligence and memory seem to have genetic loadings smaller than *g*. Thus *g* is the level at which genetic effects on intelligence are most clearly manifested. No wonder, then, that Spearman (1927) concluded that only "the most profound and detailed direct study of the human brain in its purely physical and chemical aspects" (p. 403) will allow us to fully understand the meaning of *g*.

Recent advances have enabled researchers to examine the heritability of specific traits by carrying out **multivariate genetic analyses**, which compare the effects of genes on a pair of traits independently of their individual heritability levels. The statistical indicator known as the *genetic correlation* thus tells us whether two specific traits are related, regardless of their level of genetic determination. So far, results suggest that the same genes are likely to affect different abilities, from spatial to verbal to more elementary cognitive processes. Moreover, consistent correlations between brain size, psychometric intelligence (*g*), and basic cognitive processes would be indicative of the general rather than specific effect of intelligence-related genes, manifested across different brain areas and functions. Interdisciplinary studies are rapidly facilitating the integration of different areas such as neuropsychology, cognitive psychology, behavior genetics, and differential psychology, shedding light on the underlying causal paths that determine genetic and environmental relationships in IQ.

multivariate genetic analysis analysis that compares the effects of genes on a pair of traits independently of their individual heritability levels, giving a statistical indicator known as the genetic correlation which shows whether two specific traits are related

7.8 GENETIC CAUSES OF PERSONALITY TRAITS

Owing to space constraints and the uniformity of criteria to measure cognitive ability, I have chosen to focus on the behavior genetics of intelligence rather than other traits throughout this chapter. However, behavior-genetic studies have not just been confined to intellectual ability but have also investigated personality traits. In fact, some estimate that there are more studies looking at the biological causes of personality traits than intellectual abilities. Needless to say, people are usually more interested in the heritability of intelligence than that of personality, not least because of the controversies surrounding the concept and measurement of intelligence.

Whereas extreme IQ scores tend to have direct and obvious implications in everyday life, "extreme" personalities do not, with the exception of psychopathology, have major connotations. Thus the social implications of personality and intelligence are quite different. Whilst intelligence may justify a job offer or promotion, individuals' score on personality dimensions may have little effect on their careers, even when used in occupational contexts. If, however, personality traits can significantly predict performance in educational and occupational settings, and affect a variety of real-world outcomes in general (as shown in chapter 3), the implications of the heritability of personality should not be undermined.

In a state-of-the-art meta-analytic review of personality and behavior genetics, Zuckerman (1991) concluded that:

a) There is a *substantial hereditary* aspect underlying most personality dimensions.
b) *Genetic* correlations for personality tend to *persist* throughout the lifespan (just as for intellectual abilities).
c) *Environmental* (shared environment) influences on personality traits are far *less* important than genetic ones.
d) *Non-shared* environment has a greater *impact* than shared environment, but is less important than genes, in determining personality traits.

Overall results are summarized in Table 7.2. It is noteworthy that most of these results refer to studies on the Gigantic Three inventory (Eysenck's model) or comparable instruments. This is because, until 1992 (one year after Zuckerman's review), the Big Five had little significant impact on differential psychology studies and assessment was predominantly focused on Neuroticism, Extraversion, and, to a lesser extent, Psychoticism. In fact these traits have not always been assessed with the same instrument, which may have partly contributed to the variability between studies that can be seen in Table 7.2.

It should also be noted that the samples reviewed by Zuckerman differed in age and, somewhat more, in size ($N = 151$ to 14,288). There is nonetheless a consistent pattern of results across samples, such that correlations between MZ twins are always larger than those between DZ twins. In some cases, such as Neuroticism in Tellegen et al.'s. (1988) study, differences are relatively minor, but in most studies correlations for MZ twins are at least twice as large as those for DZ twins.

If personality traits were mostly "acquired" or "learned," i.e., determined by upbringing and rearing, we would not expect such differences between DZ and MZ twins. Furthermore, if strong environmental influences occurred we would certainly expect the correlations in Table 7.2 to decrease with age. It seems clear, however, that MZ twins tend to have more similar personality traits than do DZ twins, and that these similarities tend to "hold" clearly across the lifespan. For instance, for Extraversion, the correlation between MZ is $r = .61$ at the age of 18, and $r = .54$ at the age of 54 (Pedersen et al., 1988). Thus studies on the Gigantic Three personality factors, notably the two longstanding traits of Neuroticism/Emotional Stability and Extraversion/Introversion, show that personality traits are largely inherited, that is, that there are strong biological influences on these individual differences, which, as said, are referred to the most general patterns of thought, behavior, and emotionality that make every individual unique and different from others.

Another important statistical value is that of the correlation between genetically *unrelated* siblings who were brought up in the same family (shared environment). Zuckerman's (1991)

Table 7.2 A comparison between the personality of MZ and DZ^a (correlation coefficients)

Researchers	*Age*	*Neuroticism*		*Extraversion*		*Psychoticism*	
		MZ	*DZ*	*MZ*	*DZ*	*MZ*	*DZ*
Loehlin & Nichols (1976)	*18*	.54	.22	.61	.25	.54	.32
Floderus-Myrhed et al. (1980)	*17–49*	.46	.21	.47	.20	–	–
	17–49	.54	.25	.54	.21	–	–
Eaves & Young (1981)	*31*	.47	.07	.55	.19	.47	.28
Tellegen et al. (1988)	*21*	.54	.41	.54	.06	.58	.25
Rose et al. (1988)	*24–49*	.33	.12	.46	.15	–	–
	24–49	.43	.18	.49	.14	–	–
	14–34	.41	.22	.60	.42	.70	.41
Pedersen et al. (1988)	*59*	.41	.24	.54	.06	–	–

[a] MZ = monozygotic (identical twins), DZ = dizygotic (fraternal twins).

Source: Adapted from Zuckerman (1991).

review of the literature concluded that, on average, the correlation for personality traits between these siblings is in the order of $r = .07$, that is, virtually *zero*. This is not just surprisingly low, it is also in direct opposition to the vast number of theories in developmental psychology that have long emphasized the importance of specific strategies for bringing up children. The behavior-genetic evidence reviewed here suggests that psychological eminences as diverse as Freud, Skinner, and Bandura (to cite only a few) may have largely overestimated the importance of shared environment and that the consequence of one or other educational strategy may be virtually meaningless, especially compared to the power of genes. Furthermore, most of the effects of non-genetic factors seem attributable to non-shared rather than shared environmental variables, meaning that people *other* than family members, for instance teachers and friends, would exert a bigger influence on individuals' personality development than parental rearing.

One of the most important studies about the genetic basis of personality traits was carried out by Loehlin (1992), who compared twin and adoption data on the Big Five personality traits (Costa & McCrae, 1992). This study showed that, on average, the HE for Neuroticism and Extraversion ranged from .30 to about .50 (the outbound figure is generally taken to be more reliable). These data are consistent with Eysenck's biological theory of personality, which hypothesized innate physiological differences (in cerebral arousability levels) underlying individual differences in Neuroticism and Extraversion.

Recent research has achieved unprecedented progress in mapping behavioral differences onto particular genes, an area known as **molecular genetics**. Typically, this research examines correlations between different genes and personality or intelligence scores. For instance, Lesch et al. (1996) have identified a gene associated with individual differences in trait anxiety (Neuroticism/Emotional Stability). One of the most consistent associations (see Benjamin et al., 1996) is that between the *neuroreceptor* gene, the D4 dopamine receptor (*DRD4*), and *sensation-seeking*, a trait that shows considerable overlap with Openness to Experience from the Big Five model (see section 2.11), as well as the Psychoticism trait from Eysenck's model (see section 2.6). (Because of its wider use I have focused on Openness rather than novelty-seeking or sensation-seeking, but further references to this can be found in Zuckerman, 1994). Specifically, the length of the DNA marker for the DRD4 genes seems to be one of the causes of higher sensation-seeking, such that longer **alleles** in the DNA structure are associated with higher sensation-seeking and vice versa. Thus sensation-seeking may be interpreted as an attempt to compensate for lower levels of dopamine (Plomin & Caspi, 1999).

molecular genetics an area of research that examines correlations between different genes and personality or intelligence scores and maps behavioral differences onto particular genes

allele one of two or more alternative forms of a gene that occupies the same position (locus) on paired chromosomes and controls the same characteristic

7.9 GENETIC BASIS OF MALADAPTIVE BEHAVIORS

Recent studies in differential and neuropsychology have attempted to shed light on the particular physiological processes underlying *addictive behaviors*, such as illegal substance use, smoking (which is increasingly banned in developed countries), and alcohol use and abuse. This wave of research has important clinical implications as it could help early identification of vulnerability to addictions as well as improve treatment of patients, for example by preventing harmful habits and estimating the degree of risk associated with specific genetic in-prints.

Blum et al. (2000) have argued that individuals may be genetically predisposed towards malfunctioning of the dopamine neurotransmitter, resulting in a structural "reward deficiency." Accordingly, they would experience higher levels of subjective relief/well-being and enhanced stress reduction following the act of drug ingestion.

Twin, family, and adoption studies (which have been recently reviewed by Ball & Collier, 2002) point towards salient genetic determinants of a variety of substance abuses. Typically, HE for use and abuse of alcohol, hallucinogens, stimulants, and cannabis range from .40 to .60, which is considered high. These figures have been replicated in studies looking at "initiation rates" or the likelihood of trying a substance or drug in adolescents (see Reich et al., 1998; Uhl et al., 2001). However, attempts to isolate or identify specific genes associated with addictive behaviors have so far been less successful, probably because, as with most individual difference variables, substance abuse is genetically *multi-determined*, which means there are confounding genetic determinants underlying such behaviors such that more than one gene contributes to their cause.

Aspects of personality significantly related to addictive/compulsive behaviors include broad traits such as Extraversion and Psychoticism, and more specific "primary traits" such as impulsivity and antisocial sensation-seeking. At the neurotransmitter level, these facets of behavior and psychological dispositions seem linked through the dopamine chemical (see Depue & Collins, 1999; Pickering & Gray, 1999, for reviews). For instance, Gray, Pickering, & Gray (1994) conducted an "emission tomography" study and found that the D2 receptor binding of the dopamine neurotransmitter is significantly related to impulsivity and antisocial behavior in healthy participants (see also Suhara et al., 2001). It has been argued that the *incentive motivational systems* of the brain may be involved in determining levels of Extraversion and antisocial/maladaptive impulsivity, since these traits are positively, albeit modestly, intercorrelated (Depue & Collins, 1999; Pickering & Gray, 1999, 2001). This is consistent with the view of extraverts as more "reward-sensitive" than their introverted counterparts.

The implications of the above associations with regard to substance abuse may not be as straightforward, however. Extraversion, for instance, is positively associated with constructs such as happiness, self-confidence, and life satisfaction (see chapter 3). Thus the reward-deficiency hypothesis may lead us to expect extraverted individuals to have greater potential for drug and alcohol use, when personality taxonomies suggest it is introverts who tend to experience lower self-esteem, lower levels of happiness, and lower levels of satisfaction with life. Accordingly, introverts should also be more vulnerable to addictions and represent an easier psychological "target" for addictive substances. When it comes to predicting substance abuse, it may therefore be more appropriate to look at antisocial behavior and impulsivity than the more general and seemingly "positive" trait of Extraversion (see Sher, Bartholow, & Wood, 2000, for a recent longitudinal study of this sort).

Another major personality trait associated with alcohol and drug use is Psychoticism (Newbury-Birch, White, & Kamali, 2000). This is perhaps unsurprising as Psychoticism is a far better predictor of antisocial behavior and impulsivity than is Extraversion (Eysenck & Eysenck, 1985). Studies also report an interesting interaction between Psychoticism and *gender* differences, such that men tend to be more psychotic and abusive of alcohol and drugs than are women (O'Malley & Johnston, 2002), particularly among young populations. In addition, one would also expect *cultural* factors to play a significant moderating role in determining these differences.

7.10 PERSONALITY AND INTELLIGENCE: INTERPLAY BETWEEN ENVIRONMENT AND GENES?

Although both twin and adoption studies suggest that the environment has a minor influence on the development of individual difference in personality and intelligence compared to genes, some caution is needed to interpret the implication of these findings.

Most sociologists, anthropologists, and social psychologists tend to reject the idea that genes are more important than experience (e.g., formal and informal education) in shaping our personality and intelligence. Conversely, behavior geneticists, and increasingly differential psychologists in general, seem inclined to believe that the "real" effect of genes on abilities and personality traits is underestimated by these data, mainly because of the unreliability or imperfection of psychometric instruments used to assess individual differences. Furthermore, they point out that genes may not only exert an effect on traits, but also affect environmental choices, too, implying an *interplay* between genes and environment.

The idea of an interplay between genetic and environmental factors is conceptually complex and counterintuitive, as nurture and nature have always been conceptualized at opposite ends of the spectrum. Thus philosophers and scientists alike have examined whether nature *or* nurture is responsible (i.e., the cause) of an event. Even when behavior-genetic studies estimate the degree to which one or other factors affect behavior, the assumption was that of an additive model, such that genetic + non-genetic factors = 100 percent of the variance in a phenotype. However, suggesting that genes may affect environmental choices, which in turn may affect individual difference (e.g., the development of personality traits or abilities), implies a *multiplicative* model, namely, genetic × non-genetic factors = 100 percent. Thus genetic factors are necessary not only to understand the outcome or phenotype, but also the type of environment or experience. For example, Plomin, Loehlin, and DeFries (1985) noticed that siblings' *shared* environment is influenced by genetic factors, such that activities and interests are shaped according to genetic predispositions. This hypothesis would explain why two siblings may not experience exactly the same environment even if they grow up together.

The multiplicative model of genetic–environmental influences is also important to examine possible developmental links between personality traits and cognitive abilities, an area that has been the focus of increasing research in recent times. Ever since Cattell's (1987) theory of intellectual investment, differential psychologists have considered the possibility of causal effects between intelligence and personality, such that traits may affect the development of crystallized abilities. Indeed, there are paths in the other direction, too. Chamorro-Premuzic and Furnham (2005, 2006) have argued that certain personality traits, such as Conscientiousness, may in part develop as a response to interactions between biologically based abilities and environmental demands.

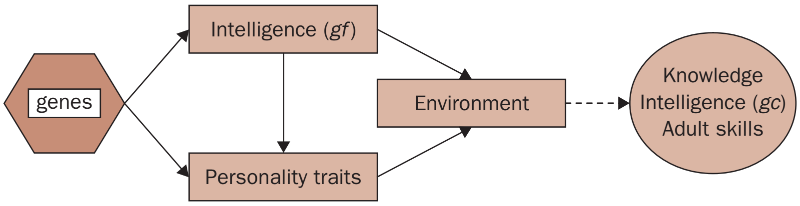


Figure 7.6 Genetic interplay: personality and intelligence.

For example, lower levels of fluid intelligence may be compensated by higher levels of Conscientiousness in order to accomplish challenging tasks (e.g., competitive university programs or jobs). If genes influence the level of intellectual investment, the effects of personality and intelligence would be confounded in environmental choices. Thus "the intelligent child will actively seek out intellectually stimulating environments – playing chess, asking parents for educational games, joining several clubs at school, reading educational magazines, and perhaps making friends who are also of above-average ability" (Cooper, 2002, p. 260). Figure 7.6 presents a graphic depiction of the premature effects of genes on shared and non-shared environments, that is, how biologically inherited factors can play an active role in shaping a child's experiences from a very early age until adulthood.

The model in Figure 7.6 may also be applied to personality traits, particularly to understand environmental choices. For example, extraverts' genetically determined lower levels of cortical arousal would lead them to *seek* stimulating or arousing environments, such as parties, social gatherings, and background music. Conversely, the genetic disposition towards introversion would be manifested in terms of higher levels of cortical arousal, which in turn would lead introverts to *avoid* similar stimulating or arousing environments. Thus introverts may be as aroused on their own as extraverts in the company of others (see again section 2.6 on Eysenck's biological theory of personality).

7.11 IMPLICATIONS FOR UPBRINGING AND EDUCATION

The idea that intelligence and personality are largely inherited has important educational implications. Educational theories and practices have been traditionally based on the assumption that environmental factors (e.g., early family experiences, upbringing, formal schooling) are the major causal determinants of adult individual differences, and this applies to many areas of psychology (e.g., social, developmental, and clinical). As stated above, eminent psychologists as diverse as Skinner, Freud, and Bandura all seemed to agree on the importance of experience in shaping individuality. It is therefore quite astonishing that the effects of genetic factors on individual difference constructs have been replicated so widely.

Whilst behavior-genetic findings may pose a big question mark against the environmentalist or social learning view of individual differences, the idea that experience has no effects on our lives is absurd. Behavior is rarely "completely genetic." A person with a genetic *predisposition* towards alcoholism will not become an alcoholic if he/she never takes a sip of alcohol. If anything, behavior-genetic findings seem to question the importance of "shared" rather than "non-shared" environment, as the effects of the latter seem substantially more significant than the former.

Another key issue is that behavior-genetic research has mainly focused on *traits*, which, although encompassing a wide range of behavioral and psychological dispositions, are not perfect measures of individual differences. Even if psychometric inventories such as the Big Five personality questionnaire provide an adequate or good estimate of individuals' personalities, they are only *generalizations* of behavior, and therefore less focused on specific behaviors that may be less affected by genes and more affected by experience (just as specific abilities seem to be less affected by experience than *g*).

HEs may also vary for extremely high or low scores on the same trait, and indeed differ for positive or negative manifestations of the same personality characteristics. For instance, Stevenson (1997) found that antisocial behavior (e.g., aggressiveness, destructive behavior, anger expression) had relatively low genetic causes, whereas the HEs for *prosocial behavior* (e.g., empathy, altruism, solidarity) were quite high. Thus "sociability" is a complex, multi-determined process that is influenced by an array of factors ranging from genes to shared and non-shared environment.

7.12 CONTRADICTING GENETICS: THE FLYNN EFFECT

Despite the robust and consistent evidence from behavior-genetic research that the major psychological differences underlying behavioral differences between individuals are of genetic origins, there are a few unsolved dilemmas that are almost in direct conflict with the findings from twin and adoptive designs presented above. The most salient inconsistency was highlighted in a series of studies conducted and reported by James **Flynn** (1987), a sociologist from New Zealand.

Flynn effect the finding by sociologist James Flynn that there are generational increases in IQ across nations

Flynn gathered large sets of cross-cultural and longitudinal data on psychometric intelligence from military databases, as several armies use IQ tests for selection. The list of countries included The Netherlands, Belgium, New Zealand, Norway, and Great Britain (see Figure 7.7). Because ability tests are usually "standardized," i.e., every newly introduced item or question is carefully

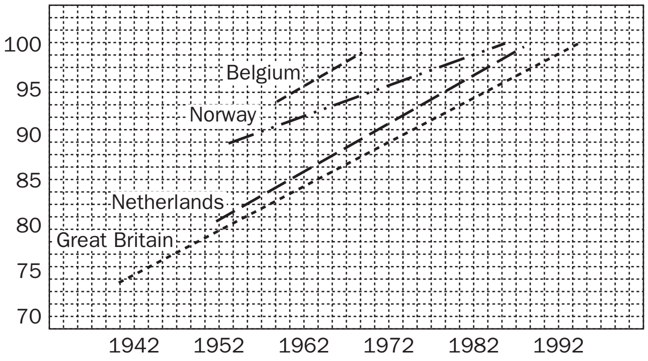


Figure 7.7 On the rise: the Flynn effect in four nations (IQ increases across time).
Source: Adapted from Flynn (1999).

balanced against old ones to prevent major changes in difficulty level and maintain similar standards, differences in scores on the *same test across time* may be interpreted as differences in "real" ability rather than the instrument. Furthermore, two different versions of the same test (say WISC 1978 vs. 1998 versions) may be administered to the same person to compare his/her performance on both versions, such that higher scores on the earlier version will indicate a generational increase in cognitive ability.

In Figure 7.7 it can be seen that there are generational increases in IQ across nations (although four nations are graphically represented in this chart, Flynn's studies extended to a larger number of countries and have been reported elsewhere, i.e., Flynn, 1987, 1998, 1999), by about 15 points (1 SD) every 50 years. It is also noteworthy that most increments have been found in tests of fluid (*gf*) rather than crystallized (*gc*) intelligence, which means increases in ability could not have been caused by improvements in educational factors, such that, say, current generations are more knowledgeable or educated than former ones. Rather, it is scores on so-called "culture-free" tests (e.g., non-verbal, logical, mathematical) that improved most over time, suggesting current generations are mentally "quicker" and "faster" than older generations when it comes to learning new things.

The question as to why IQ scores seem to have improved over time and why today's generations may be brighter than older ones is complex. Several hypotheses have been put forward, from technical assumptions on the structure of psychometric tests (notably, familiarity with questions or "type" of items) to more fundamental theories, including the role of nutritional advances (Lynn, 1990). For example, a better diet has a positive effect on physical health (a healthier body), which in turn translates into more efficient and effective brain functioning, including the cognitive processes that are required to excel on tests of fluid intelligence.

7.13 SUMMARY AND CONCLUSIONS

This chapter has examined the role of genetic and non-genetic (i.e., shared vs. non-shared environment) influences on individual difference factors. As seen:

1. Behavioral traits, such as intelligence and personality traits, are largely inherited, such that genetic resemblance is correlated with phenotypic resemblance (this is particularly noticeable in twin studies comparing non-identical with identical twins). Although traits are also influenced by non-genetic factors, such that identical twins reared together are psychologically more similar than those separated after birth, genetic similarity is far more important than shared environment. Indeed, adoptive siblings are no more similar to each other than two people picked randomly from the streets (Pinker, 2002), and adopted children tend to resemble their biological rather than adoptive parents.
2. Non-shared environment plays a larger role than shared environment in determining individual differences in such traits as personality and intelligence. Thus early childhood experiences are less influential than subsequent experiences outside the family home (e.g., primary and secondary school, childhood friends).
3. Although the nurture vs. nature debate has a longstanding history in psychology, it assumes that genetic and non-genetic factors have additive or independent effects on behavior. However, genetic and environmental influences are multiplicative or interactive, such that the effects of nurture on behavior may be partly predetermined by nature. This idea is useful to integrate the traditionally opposite views of nurture and nature: genetic factors may influence environmental choices, which in turn may influence behavioral outcomes. Thus nurture may mediate or moderate the effects of nature on personality and intelligence.

In chapter 8, I will examine alternative approaches to the study of intelligence. These approaches emphasize the role of emotional, interpersonal, and social factors as determinants of human achievement beyond IQ.

KEY READINGS

Eysenck, H. J., & Eysenck, M. W. (1985). *Personality and individual differences: A natural science approach*. New York: Plenum.
Flynn, J. R. (1999). Searching for justice: The discovery of IQ gains over time. *American Psychologist*, *54*, 5–20.
Plomin, R., & Spinath, F. M. (2004). Intelligence: Genetics, genes, and genomics. *Journal of Personality and Social Psychology*, *86*, 112–129.
Zuckerman, M. (1991). *Psychobiology of personality*. Cambridge: Cambridge University Press.