Chapter 12

Behavioural Genetics: The Study of Differences Martin Lalumière

A large part of psychological science is concerned with identifying, cataloguing, and explaining individual differences. One does not need a degree in psychology to observe that there are enormous differences in how people think, feel, and act. Everyone recognizes differences in the personalities of one's family members, for example. These differences exist even though family members live in the same culture, historical era, political climate, economic circumstances, and house (at least while growing up). Think of five of your friends: Even though they have many things in common (they are probably close in age, and they all like you), I would bet that they differ in how smart they are, how outgoing they are, how emotionally intense they are, how political they are, and so on. But organizing and explaining the origins of these differences, whether cognitive, emotional, or behavioural, is more difficult.

Behavioural genetics is one of many ways to study the origins of individual differences. It is an important topic to study because, unlike many other areas of psychological research, it has produced a large body of knowledge that has survived the test of time. The results of this field of psychology stand as close to facts as any result in psychology. Many behavioural geneticists have moved on to other topics of research because they have concluded that most of their original questions have been answered.

Behavioural genetics is about partitioning the sources of individual differences in any trait that can be measured reliably. The fundamental question is how much of the observed variability in a given trait can be explained by the fact that people have different genes, and how much can be explained by the fact that people have been exposed to different environments. One could turn the question around and ask how much of the similarity among people can be accounted for by their genetic similarity, and how much can be accounted for by their exposure to similar environments. Although the name of the discipline emphasizes genetics, the focus is on both genes and environment. In fact, as we will see, this discipline has much to say about the importance of the environment in creating individual differences.

12.1 Research Methods

Behavioural geneticists are lucky. There are known genetic differences among people, such that the size of the genetic difference can be compared to the observed difference in the trait under study. Similarly, there are known environmental differences that can be related to trait differences. When it comes to genetic differences, the level of precision of the magnitude of the difference is quite good. We know that, on average, siblings share 50% of their polymorphic genes[1], whereas cousins share 12.5%. Therefore, if differences in a trait (say, intelligence) can be explained by genetic differences, then siblings should be more similar in intelligence than cousins. Of course, siblings could be more similar because they grew up in the same house, whereas cousins did not (in many cultures cousins do grow up in the same house, but here we will assume that they do not).

The degree of environmental differences is not as easy to quantify. We know that siblings are exposed to more similar environments than cousins, but how much more similar is unclear. Siblings grow up with the same parents, are exposed to the same physical environment (the house, the number of books on the shelves, the family income, the neighbourhood) whereas cousins grow up with different parents, perhaps in different economic circumstances, perhaps in different neighbourhoods, etc. All that we know for sure is that siblings are exposed, on average, to a more similar environment than cousins. The exact degree of similarity requires precise measurement, something that is not done very often.

The two main statistics of behavioural genetics are *heritability* (h^2) and *environmentality* (e^2). The values for both statistics vary from 0 to 1, where 0 means that none of the observed variance can be accounted for by genes (for heritability) or the environment (for environmentality), and where 1 means that all the variance can be accounted for by genes (or the environment). In the classic research designs described below, h^2 and e^2 are mutually exclusive, such that the total amount of observed variance is equal to the sum of h^2 and e^2.[2] Heritability should not be confused with inheritance, the latter meaning shared genes passed on by parents. A trait can have low heritability but be completely inherited (e.g., binocular vision). Can you think of the reason for this?

There are two main research designs used to tease out the effects of genes and environment on phenotypic differences.[3] The first is the twin and sibling design and the second is the cross-fostering or adoption design. Of course, scientists do not experimentally create twins or force adoption of siblings. These events happen naturally and

[1] Polymorphic genes are those that come in different versions (e.g., genes having to do with eye colour). In contrast, monomorphic genes are those that all members of a species share.

[2] Technically, the formula also includes covariance and measurement error, but for pedagogical purposes we can ignore these terms here.

[3] The phenotype refers to the manifest (or observed) characteristics of an organism, whereas the genotype refers to the genetic complement.

scientists take advantage of them to study the influence of genes and environment on the development of individual differences.

There are two types of twins. Identical or monozygotic twins (MZ) share all of their genes (100% relatedness) and non-identical or dizygotic twins (DZ) share only 50% on average. DZ twins are just like regular siblings, except that they were in the same womb at the same time. Thus, if genetic differences account for most of the difference in a given trait, MZ twins should be about twice as similar as DZ twins. Of course, MZ twins might be more similar than DZ twins because people treat them the same way (after all, they are very similar physically) or for other reasons. Therefore, scientists have also studied a rare group of people: MZ and DZ twins who have been reared apart. In this case, any greater similarity in MZ than in DZ in an observed trait is likely due to genetic similarity and not environmental similarity.

In cross-fostering designs, unrelated siblings are reared together. Therefore, any similarity is due to the fact that these individuals are reared in the same environment, not to the fact that they share similar genes. One can also examine the degree of similarity of foster or adoptive parents and their genetically unrelated children.

12.2 Estimating Heritability and Environmentality

Table 12.1 shows the degree of similarity in intelligence as a function of degree of genetic similarity. As you can see, pairs tend to be more similar in intelligence as they are more similar genetically. The results also show that being exposed to more similar environments (being reared together rather than apart) is associated with greater similarity in intelligence. These results are very typical of behavioural genetics findings for many different traits: part of the observed individual differences can be explained by genetic difference, and part can be explained by environmental differences. This may seem like a trivial finding to you, but for a very long time psychologists and other social scientists thought that people's experiences were the sole determinants of their behavioural characteristics.

There are many different ways to estimate h^2 from twin and sibling studies. The intra-class correlation for a given trait in MZ twins raised apart directly estimates broad-sense heritability (h^2). Broad-sense heritability reflects all genetic effects that can only be shared by identical twins.[4] In the example given above, broad-sense heritability of IQ is 0.72.

Twice the difference in the correlation for MZ twins reared together and DZ twins reared together estimates narrow-sense heritability, assuming absence of non-additive effects.[5] In the example above, narrow-sense heritability is $2 * (0.86 - 0.60) = 0.52$. Twice the correlation for parent and offspring living apart from birth is an estimate of narrow-sense heritability that does not require the assumption of absence of non-additive effects (because these cannot be passed from parents to offspring). In the

[4] Broad-sense heritability = additive effects of genes at specific locations + dominance (non-additive effects of genes at a single location) + epistasis (interaction of genes at different locations, including different chromosomes). Dominance and epistasis can lead to MZ correlations that are more than twice as large as DZ correlations.

[5] Narrow-sense heritability includes only additive effects of genes and is always equal to or less than broad-sense heritability.

Pair Relations	Genetic Similarity	Similarity in IQ (r)
Identical twins raised together	100%	.86
Identical twins raised apart	100	.72
Non-identical twins raised together	50	.60
Biological siblings raised together	50	.47
Biological siblings raised apart	50	.24
Parent-offspring together	50	.42
Parent-offspring apart	50	.22
half-siblings	25	.34
cousins	12.5	.15

Table 12.1: Similarity in intelligence (based on intra-class correlation (r)) as a function of degree of genetic similarity (data from Bouchard & McGue, 1981).

example above, narrow-sense heritability is 2 * 0.22 = 0.44. As you can see, different calculations produce slightly different results. What matters is the range of values obtained across many studies using different designs. In the case of IQ, that range is centered on 0.50 for narrow-sense heritability and 0.75 for broad-sense heritability. Heritability of IQ increases with the age of the subjects in the study. Can you think of a reason for this counter-intuitive finding?

The correlation between unrelated siblings reared together directly estimates environmentality (e^2). Another way to assess e^2 is to subtract h^2 from 1.0 in studies of MZ and DZ twins reared together, assuming perfect reliability of the measure. Another way is to calculate the difference in the correlation obtained for MZ twins raised apart and MZ twins raised together. For IQ, and using data provided by Bouchard and McGue (1981), these methods produce e^2 values of 0.34, 0.48, and 0.14. The value of 0.48 is inflated because measures of IQ are in fact not perfectly reliable.

12.3 Some General Findings

It is now well accepted that most psychological characteristics show substantial heritability. These include, as we have seen, intelligence, and also more specific cognitive abilities, as well as different aspects of psychopathology (e.g., schizophrenia, depression, and anxiety), antisocial tendencies, and personality. Bouchard (1994) reported that the five major dimensions of personality (extraversion, neuroticism, conscientiousness, agreeableness, and openness) show heritability values of 0.40 to 0.50. It is also well accepted that environmentality accounts for a large portion of individual differences in these domains.

One of the most interesting findings of behavioural genetics has to do with the nature of environmental effects on the development of individual differences. Behavioural geneticists distinguish between two types of environments: shared and non-shared. The shared environment refers to the part of the physical and social environment that is common to all siblings. For example, siblings live in the same house, have the same number of books in the house, live in the same neighbourhood, and have the same number of parents. The non-shared environment refers to the part of the physical and social environment that differs among siblings. Siblings have a different birth order, may be treated differently by parents, and so on. Results of behavioural genetics studies suggest that the type of environment that most influences the development of individual differences is non-shared. That is, aspects of the environment that are shared by all siblings appear much less important in influencing the development of individual differences than aspects that are not shared by siblings. In fact, siblings (other than monozygotic twins) tend to be quite different from one another in their personalities, despite sharing similar genes and living in a similar environment (Plomin & Daniels, 1987). Elsewhere we have suggested that there might be an evolved family process that accentuates sibling differences (Lalumière, Quinsey, & Craig, 1996). For some characteristics, the longer MZ twins live together, the more different they become.

Sociologists and psychologists have traditionally studied environmental causal factors that are part of the shared environment (e.g., socioeconomic status, overall parental affection). They are now turning their attention to possible causal agents that are not experienced similarly by siblings.

12.4 Some Limits and Cautions

All research methodologies have limits and require certain assumptions (statements of fact that are taken as true but that cannot be directly examined). Behavioural genetic designs have well-known limits and well-specified assumptions. Results of individual studies have to be interpreted in the context of these limits and assumptions. For example, a study of twins reared apart assumes that twins are reared in a range of environments that is similar to the natural range of environments found in human families. This may not be true, because adoptive families are screened for suitable environments for adoptee placements. This means that the range of adoptive environments is smaller that what is found generally, resulting in an overestimate of h^2 and an underestimate of e^2.

One important cautionary statement is that heritability and environmentality statistics refer to population values at a given point in time. To say that height has a heritability of 0.80, for example, says nothing about the importance of genes versus environment in explaining your own height. Your height is completely determined by both your genes and your environment—if one or the other didn't exist, you would have no height. Heritability has to do with explaining differences among a group of people. The fact that some people in this class are shorter and others taller is mostly caused by the fact that people have different genes (rather than caused by exposure to different environments). Also, the heritability of height has increased from 0.50 to 0.80 in the last 50 years, clearly showing that it is a dynamic value. Can you think of why heritability of height is higher today than it was 50 years ago?

Another caution is that heritability says nothing about the mutability (the potential to change) of a characteristic. Although IQ is highly heritable, cognitive abilities can be greatly improved or suppressed through exposure to certain environments. IQ scores have increased constantly over the last 100 years (so much so that standard IQ tests have to be re-normalized on a regular basis), and few people believe that this change is due to changes in the gene pool. Behavioural genetics speaks to what can be observed at a given point in time, not to what can be done about improving the human condition.