house. Accessible and comprehensive listing of self-help organizations in the United States.

Keith Humphreys

TWINS. The use of twins in research on the causes of individual differences in mental and physical characteristics was introduced by Sir Francis Galton (1876, 1883), who was the first to note that the existence of two types of twins, identical and fraternal. He afforded a method by which it was possible to assess the relative effects of "nature and nurture" in the development of individual differences. His insight later became known as the classical twin method. Galton himself never applied it in any precise, quantitative way because he lacked the objective, quantitative measures of behavioral traits on which correlation analysis depends and also the essential statistical tools. Karl Pearson did not invent the product-moment correlation until 1896, and Sir Ronald Fisher had not yet invented the analysis of variance, yet these statistical methods are required for the classical twin method to yield a quantitative interpretation when applied to a metric trait. Galton, however, collected many anecdotal examples of the high degree of behavioral resemblance between identical twins as compared with the lesser resemblance between fraternal twins and pairs of singleton siblings. He observed that when sets of identical twins are compared alongside sets of fraternal twins, the relative influences of nature and nurture on many types of behavior appeared to be of nearly comparable magnitude to their generally obvious effects on visible physical characteristics. He asserted, "There is no escape from the conclusion that nature prevails enormously over nurture when the differences of nurture do not exceed what is commonly to be found among persons of the same rank of society and in the same country" (Galton, 1876, p. 576). [*See the biographies of Fisher, Galton, and Pearson.*]

Galton's essential method has been applied in modern times, but with greater psychometric and statistical sophistication, to the study of the relative effects of heredity and environment on many types of behavior, particularly mental abilities and personality traits (Bouchard & Propping, 1992; Eaves et al., 1989). The twin method has proved so valuable in the genetic study of physical and mental afflictions that many countries now maintain national twin registries to provide subjects for genetical research.

Types of Twins

Identical, or monozygotic (MZ), twins result from a single fertilized ovum, or zygote, which splits in the early stages of mitosis to produce two individuals who carry exactly the same complement of genes; that is, they are clones, with identical DNA. Conjoined twins are the rare occurrence of an incomplete separation of the zygote (about 1 in 200 MZ twin births). MZ twins are, of course, always the same sex.

Fraternal, or dizygotic (DZ), twins result from two separate ova that have been fertilized by separate sperm. Hence DZ twins are genetically as much alike as ordinary full siblings born as singletons, with each individual inheriting a random half of each parent's genes. Like a pair of ordinary siblings, DZ twins can be of the same or opposite sex. In general, DZ twins are, on average, approximately half as genetically similar to one another as MZ twins. Because of the random assortment of the parental genes in the formation of ova and sperm, the degree of genetic resemblance in a specific trait between the members of a given pair of DZ twins can vary widely among different pairs. The two members of the pair of DZ twins can be nearly as much alike as MZ twins on a particular trait, especially if it is controlled by very few genes, or they can be much more dissimilar than most DZ twins or single-born siblings. It is only on average that DZ twins, theoretically, are half as similar genetically as MZ twins.

Frequency of Twinning

Approximately 1 pregnancy in 89 produces twins, although this figure varies in different populations. More specifically, in every 1,000 pregnancies there are, on average, 3 to 4 MZ twins and, in the United States, 7 to 12 DZ twins. Unlike MZ twinning, which occurs at random and with the same relative frequency in every population, the frequency of DZ twinning varies according to the age of the mother (increasing with maternal age), parity (increasing with the number of previous pregnancies), and race: The frequency range per 1,000 births is 2 to 7 for Asians, 7 to 13 for Europeans, and 45 to 50 for sub-Saharan Africans. A woman's probability of giving birth to DZ twins is hereditary or familial, but a hereditary tendency for MZ twinning has not been clearly established.

Zygosity Diagnosis

When using twin data for genetical research, it is important to obtain an accurate diagnosis of the twins' zygosity (whether MZ or DZ). There are several methods of zygosity diagnosis, which differ much less in accuracy than in cost or convenience (Bulmer, 1970). The choice of method depends on the size of the twin sample, the cost, the personal accessibility of the subjects for examination, and the importance of minimizing error for the purpose of the particular study. The various methods have misclassification rates ranging from zero to about 10%. When samples are large and there is a good estimate of the error rate for a particular method of zygosity diagnosis, it is possible to apply a statistical correction in the data analysis that estimates the MZ and DZ correlations as if they were free of classification errors. The less reliable methods can be used in combination to decrease the overall error rate. Although MZ twins are generally born with one placenta and DZ twins with two, this and other obstetrical information, which is not always available or may be unreliably reported, is nowadays seldom used to ascertain zygosity.

The simplest and least expensive method is a self-report questionnaire, given to the twins or their parents, asking questions about eye color, hair color, hair whorls, degree of facial resemblance, height, weight, and other visible features. Such questionnaires are about 95% accurate. Monozygosity can be ruled out through a simple test for the twins' ability to taste the synthetic chemical phenylthiocarbamide (PTC), which is a single-gene trait. The fingerprints of MZ twins are as much alike as the fingerprints from the two hands of one individual, whereas DZ twins have distinctly different fingerprints. The number of matching blood types for a pair of twins establishes zygosity with an error rate inversely related to the number of different blood groups and their population frequencies. A skin graft between any two individuals except MZ twins is rejected and is a definitive test of zygosity. Today, however, when 100% accuracy is required, the method of choice is to use DNA markers, but this method, though noninvasive. is still costly and time-consuming.

Misclassifying twins' zygosity attenuates the estimate of genetic variance yielded by the classic twin method, because the MZ correlation is decreased by including misdiagnosed DZ twins in the MZ twin sample, while the DZ correlation is increased by including misdiagnosed MZ twins in the DZ twin sample.

Twin Correlations

The degree of resemblance between twins cannot be measured properly by the simple Pearson product-moment coefficient of correlation, *r*. which can yield many different values depending on the order in which members of each twin pair are assigned to each of the correlated variables in the bivariate distribution. To overcome this shortcoming of *r* for research on twins, Pearson proposed the double-entry method for calculating the correlation coefficient, whereby each pair of twins (say, twins A1 and A2) is entered twice, in the orders A1, A2 and A2, A1, before calculating the Pearson *r*. This method, however, has now been replaced by the intraclass correlation, r_i, invented by R. A. Fisher expressly for representing the correlation between two (or more) variables when their means and standard deviations in the population are assumed not to differ. This assumption statistically allows the sample value of r_i to have one more degree of freedom and hence a smaller standard error than the double-entry Pearson *r*. The intraclass correlation is defined in terms of the analysis of variance. Its theoretical population value is $\rho = \sigma_B^2/(\sigma_B^2 + \sigma_w^2)$, where σ_B^2 is the population variance *between* twin pairs and σ_w^2 is the population variance *within* twin pairs. The estimated value of ρ calculated from a sample of twins is $r_i = (V_B - V_w)/(V_B + V_w)$. where V_B is the sample variance *between* twin pairs and V_w is the sample variance *within* twin pairs. Because of the common practice of squaring the correlation coefficient to determine the proportion of variance in one variable that can be predicted by another variable, it is important to note that the correlation between twins (either MZ or DZ, or any other kinship), whether Pearson's double-entry *r* or Fisher's intraclass r_i, represents a proportion of the phenotypic variance and therefore should not be squared. (Henceforth, for simplicity of notation, the intraclass correlation. which will be used exclusively throughout, is symbolized simply as *r*.)

Monozygotic Twins Reared Apart

MZ twins separated in infancy and reared apart (MZA) are extremely rare; fewer than 170 such MZ pairs are reported in research literature, not counting the 53 MZ pairs reported by Burt, which are now conventionally excluded because their authenticity has been questioned (Mackintosh, 1995). Horatio H. Newman, Frank N. Freeman, and Karl J. Holzinger (1937) published the first important study using MZA to estimate the heritability of intelligence. MZA are particularly valuable for this purpose, because theoretically the intraclass correlation coefficient (r_{MZA}) between MZ twins reared apart in random or uncorrelated environments provides a direct estimate of the proportion of total genetic variance for the measured trait, which is also termed its *broad heritability*, or h_B^2 (i.e., the proportion of the total phenotypic variance attributable to all genetic influences—additive, dominant, and epistatic). In other words, theoretically $r_{MZA} = h_B^2$. (The square root of the broad heritability, or h_B is equal to the correlation between the genotypic and phenotypic values of the characteristic in question.) The degree of accuracy with which an observed correlation based on a sample of MZ twins actually estimates the population value of h_B^2 can only be answered empirically, by determining whether the MZ sample meets the assumption that they were reared in uncorrelated environments that also represent the range of environmental variation in the population to which the value of $r_{MZA} = h_B^2$ is to be generalized. Also, like any correlation, r_{MZA} has a standard error, which is inversely related to the number of twin pairs in the sample. Twin correlations are also attenuated by measurements that have imperfect reliability; the correlations can be statistically disattenuated if the reliability coefficient of the measurements in known.

If there is a significant correlation between separated twins for certain features of the environments in which they were reared, it is then necessary to determine the degree to which the correlated environmental variables are trait relevant (i.e., correlated with the trait in question). For example, if it is found that r_{MZA} for IQ is .75 in a given sample, and it is found that some aspect (X), of the twins' environments is positively correlated between twins, then we must ask whether variable X is relevant to IQ by determining its correlation with IQ. If the twin correlation for trait-relevant environmental variables is statistically significant, it can be taken into account in a path model for estimating the twin correlation for the trait of interest independent of the environmental effect (Bouchard, 1997, pp. 144–145). In doing this, one has to guard against the risk of statistically controlling the effects of certain environmental variables that have a substantial genetic component themselves, such as the education and socioeconomic status of the probands' biological parents. Other personal attributes, such as physical appearance, should also be examined as possible trait-relevant variables. It has been argued, for example, that MZ twins are highly similar in IQ because they look so much alike and therefore presumably are treated alike by others. This conjecture has been invalidated empirically by finding that "looks" are negligibly correlated with IQ (Bouchard, 1997).

The Classical Twin Method

This is based on the correlations of a particular metric trait between monozygotic twins reared together (MZT) and dizygotic twins reared together (DZT). Researchers usually obtain the DZT correlations separately for sets of same-sex and opposite-sex twins and combine these groups only if there is a nonsignificant difference between the correlations. The logic of the twin method is that the phenotypic correlation between MZT pairs (r_{MZT}) comprises the proportion of genetic variance shared in common by the twins (V_{GC}), which for MZ twins is the total genetic variance, or 1 V_{GC}, plus the environmental variance they have in common (V_{EC}). The DZT correlation (r_{DZT}) comprises one-half of the genetic variance ($V_{GC}/2$) plus the shared or common environmental variance (V_{EC}). The genetic and environmental components of the DZT correlation are subtracted from the corresponding components of the MZT correlation:

$$\begin{aligned} r_{MZT} &= 1\ V_{GC} + V_{EC} \\ r_{DZT} &= \tfrac{1}{2}\ V_{GC} + V_{EC} \\ \hline r_{MZT} - r_{DZT} &= \tfrac{1}{2}\ V_{GC} + 0 \end{aligned}$$

Hence the formula $2(r_{MZT} - r_{DZT})$ estimates the proportion of the total variance of the trait measurements that is attributable to genetic variance (V_G), which is an estimate of the heritability (h^2) of that trait. The proportion of environmental variance, e^2, is $1 - h^2/r_{XX}$, where r_{XX} is the reliability coefficient for the measurements. The component attributable to the shared, or common, environment is estimated by $e_c^2 = r_{MZT} - r_{MZA}$. The component attributable to the unshared, or unique, environment is estimated by $e_u^2 = 1 - r_{MZT}/r_{XX}$. In the case of IQ, the source of the unique environmental variance, e_u^2, which is better termed nongenetic variance, seems to be a host of virtually random prenatal and postnatal microenvironmental conditions with largely biological effects (Jensen, 1997).

This simple formulation may provide only a rough estimate of h^2, because all of its assumptions are usually not met. The model assumes entirely additive genetic variance and random mating of the twins' parents. These assumptions, however, are open to empirical investigation, the results of which can be used in more complex analytic models to obtain a more accurate estimate of h^2 (Neale & Cardon, 1992). For traits that have dominance variance, as does IQ for example, r_{DZ} is decreased, thereby inflating the estimate of h^2. Assortative mating (implying a genetic correlation between the twins' parents for the trait in question) increases r_{DZ}; assortative mating, however, does not affect r_{MZ}. (Jensen, 1978). The decrease in r_{DZ} caused by dominance may or may not balance out the increase in r_{DZ} caused by assortative mating. More complex models, therefore, take genetic dominance and assortative mating into account to derive a more accurate estimate of h^2 from the twin data. Another assumption is that the similarity of the twin's common environment, V_{EC}, is the same for the MZ and DZ twins. But it can be argued that MZT twins are more alike in a given trait because they are treated more alike by parents and peers than are DZT twins. Whether this is true and what effect it may have on the estimate of h^2 as calculated from the twin method is wholly an empirical question. In the case of IQ, it has been answered by obtaining the correlations for MZ twins whose parents mistook them for DZ, and for DZ twins who were mistaken for MZ, and treated them accordingly. In these specially selected samples, the MZ and DZ correlations were not significantly different, on average, from the typical MZ and DZ correlations in all other studies.

Typical Twin Correlations

Correlations reported in the literature for both MZ and DZ twins vary over a considerable range depending on many conditions, such as sample size, the population sampled, the particular trait, the age of the subjects, restriction of variance on the measured trait, differences in the reliability of the trait measurements, and statistical sampling error. The average correlations for IQ based on nearly all of the MZ and DZ correlations reported in the world literature (excluding Burt's data) have been determined as follows: MZA = 0.75, MZT = 0.86, DZT = 0.60 (Bouchard et al., 1990). For various personality traits, twin correlations range widely and, with a few exceptions, are generally lower than for IQ (Eaves et al., 1989).

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Arthur R. Jensen

TYLER, LEONA E. (1906–1993), American counseling psychologist. Leona E. Tyler's psychological legacy covers research, theory, well-organized textbooks, and significant service to the profession. Her specialties were individual differences, interest measurement, human development, and counseling psychology. She consistently pursued research and theory to support professional practice aimed at bettering the human condition, including the peace movement. Her work as a counselor, researcher, writer, teacher, and graduate school dean mutually informed and influenced her research and writing. With astounding clarity, she integrated ideas and communicated the complexities of human multipotentiality.

Tyler gained a background in individual differences from her graduate work at the University of Minnesota. Her Ph.D. was granted in 1941, the year after she had joined the psychology faculty at the University of Oregon. She published one of the first books on individual differences, *The Psychology of Human Differences* (New York, 1947) and later published *Tests and Measurements* (New Jersey, 1963). She challenged traditional assessment practice by suggesting that tests be used to increase client self-awareness as well as for diagnosis or selection. She shifted the field's focus away from psychometrics for classification and directed inquiry toward the developmental and learning processes that influence how people develop differences.

Founding one of the first university counseling centers at the University of Oregon, Tyler provided direction to counseling as a specialty as it was emerging from the influences of other fields. With her early research in career development, she encouraged counseling psychology to stay focused on vocational development and the real-life problems of ordinary people. Her book *The Work of the Counselor* (New York, 1953) was the leading textbook for several generations of professionals, addressing personality theory and lifespan development. *Clinical Psychology* (with Sundberg & Taplin, New York, 1962) was also a leading textbook. She was a pioneer in considering cross-cultural and gender differences and highlighting the importance of both environmental and individual influences on development.

Tyler developed a card-sort method, the Choice Pattern Technique, to examine people's cognitive structures for organizing choices. Her "theory of possibilities" proposed that in most life situations choices are required, that opportunities are made by the individual as well as offered by the environment, and that individuals can actualize only a fraction of their possibilities. In later writings (e.g., *Individuality*, San Francisco, 1978), she strove to shift psychologists' concerns from individual differences to individuality and from trait psychology to inclusion of the whole person in the life history. Tyler suggested that counselors assist clients with making choices when they feel confused by all the possibilities in a complex world. She later utilized this theory to investigate how scientists become limited in what they choose to study. In *Thinking Creatively* (San Francisco, 1983) she suggested that science would be enriched if different paradigms could coexist and inform each other.

An active leader in both her local and professional communities, Tyler was respected and trusted for her intelligence, fairness, warmth, and decisiveness in both