The Importance of Twin Studies for Individual Differences Research

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Twin research designs and methods are valuable tools for examining genetic and environmental influences on behavioral and medical characteristics. A review of the biological bases of twinning and descriptions of 10 research designs are presented. Findings from a selected sampling of twin studies of learning disabilities, personality and temperament, attitudes, psychopathology, and social behavior are summarized. The findings are discussed with special reference to the activities of mental health practitioners and counselors.

The underpinnings of behavioral similarities and differences among people have triggered fascination and debate for many years. Twin studies provide a powerful vehicle for examining genetic and environmental influences on individual differences in behavior. The usefulness of twin methods for understanding human developmental processes is becoming increasingly appreciated by researchers in many behavioral science and medical science disciplines. The growing number of newly established research centers, twin registries, and publications reflects current enthusiasm and commitment to twin research designs and methods.

Trends toward increasing professional specialization require that representatives from related disciplines exchange concepts and findings with one another. Knowledge associated with a specific area may suggest novel methods of data collection, data analysis, interpretation, and application for other areas. Several recent excellent examples [e.g., *Child Development, 54*(2), (1983) Special Section on Developmental Behavior Genetics; *American Psychologist, 44*(2), (1989) Special Issue: Children and Their Development: Knowledge Base, Research Agenda, and Social Policy Application] are available. This article attempts to demonstrate the importance of twin studies for individual differences research for mental health practitioners, counselors, and individuals in related areas.

Knowledge of the different types of twins is requisite to understanding the logic of twin methodology. The biological bases of twinning are reviewed in the next section, followed by a survey of designs and methods. Findings from psychological and medical studies using twins will then be presented. Many of the findings, such as recent data comparing personality similarity in monozygotic (MZ) twins reared together and MZ twins reared apart, provide a fresh perspective on the relative effects of heredity and environment on individual differences in behavior. Such information may suggest more varied causes and treatments of behavioral pro&ems for psychologists who provide counseling and related services.

BIOLOGICAL BASES OF TWINNING

Types of Twins

There are two types of twins: identical or *monozygotic* (MZ) and fraternal or *dizygotic* (DZ). Monozygotic twins result when a single fertilized egg divides (Vogel & Motulsky, 1979), between 1 and 14 days following conception (Bryan, 1983). The members of MZ twin pairs share all their genes in common and are, with rare exception (Vandenberg 1966; Dallapicolla, Stomeo, Ferranti, DiLecce, & Purpura 1985), always of the same sex. Given their genetic identity, behavioral and physical differences between MZ twins are associated with differences in their environments. Differential environmental effects may occur at either the prenatal, perinatal, and/or postnatal levels. Some examples include fetal transfusion (prenatal), order of delivery (perinatal), and accident or injury to one twin (postnatal). Monozygotic twins represent approximately one-third of twins born among Caucasian populations. The MZ twinning rate of 3–4 per 1,000 maternities (Bulmer, 1970) remains fairly constant across ethnic groups and geographical locations.

Dizygotic twins result when two separate eggs are fertilized by two separate sperm. Dizygotic twins (and ordinary siblings) share 50% of their genes, on average, by descent. The theoretical range of shared genes for same sex-pairs is 0%–100%, but a more realistic range is 25%–75% (Pakstis, Scarr-Salapatek, Elston, & Siervogel, 1972). Dizygotic twinning represents approximately two-thirds of twins born among Caucasian populations; one-third of all twins are DZ same-sex pairs and one third of all twins are DZ opposite-sex pairs. The DZ twinning rate is lowest among Oriental populations (approximately 2 per 1,000 births), intermediate among Caucasian populations (8 per 1,000 births), and highest among Black populations (as high as 57 per 1,000 births in parts of Nigeria) (Bulmer, 1970).

More detailed information on the biology of twinning is found in Bulmer (1970), Bryan (1983), MacGillivray, Campbell, and Thompson (1988), and the journal *Twin Research.*

Zygosity Diagnosis

Zygosity diagnosis refers to the classification of twin pairs as monozygotic or dizygotic. This procedure is a critical first step in research because misclassification can yield incorrect estimates of genetic and environmental influences on traits of interest (Plomin, DeFries, & McClearn, 1990). Blood-typing is the most objective, easily available method for diagnosing zygosity. Lykken (1978) demonstrated that, when cotwins are compared across eight blood group systems, four serum proteins, six red blood cell enzymes, fingerprint ridgecount, ponderal index, and cephalic index, the probability of misdiagnosis is less than .001. Blood group differences indicate DZ twinning with complete certainty. An absence of blood group differences permits assignment of MZ twinning *with a high degree of certainty;* in rare instances, DZ twins may share all measured blood groups in common, a situation that is possible because of common parentage. Other objective methods for zygosity de-

termination include physical resemblance questionnaires, dermatoglyphic analysis (studies of fingerprint patterns and/or fingerprint ridgecount), and inspection of placental membranes. Descriptions of these methods are found in Vogel and Motulsky (1979), and assessment of their comparative accuracy is reported in Segal (1984a).

Factors Responsible for Twinning

Monozygotic Twinning. The biological bases of monozygotic twinning are not well understood. MZ twinning is believed to occur randomly, although recent evidence suggests that MZ twins resulting from delayed zygotic splitting represent hereditary transmission (Carter-Saltzman 1979; Levy, 1981; Parisi, Gatti, Prinzi, & Caperna 1983). Delayed splitting of the zygote has been associated with "mirror-imaging" of selected physical traits among approximately 25% of MZ twin pairs (Springer & Deutsch, 1985). This process may partly explain the increased incidence of left-handedness among twins, as compared with nontwins (20% versus 12%).

Dizygotic Twinning. A variety of factors have been associated with dizygotic twinning. These factors include advanced maternal age, parity, increased maternal height and weight, use of fertility drugs and contraceptives, social class membership, birth order, specific blood group characteristics, conceptions occurring after periods of sexual abstinence, and available nutritional supply (Nylander, 1975; Corney, Seedburgh, Thompson, Campbell, MacGillivray, & Timlin, 1981; Clark & Martin, 1982; Wyshak, Honeyman, Flannery, & Beck, 1983; James, 1983; Garza-Chapa, Escobar, Cerda, & Leal-Garza, 1984; Elwood, 1985). Ethnic differences in the DZ twinning rate have been associated with differences in many of these characteristics (Nylander, 1975). The tendency toward DZ twinning may be genetically mediated, although the precise mode of transmission has not been established.

TWIN RESEARCH METHODOLOGY

Twin Research Designs

Ten designs have been used in twin research. The logic of the classic twin method and variations of this method are described below. A discussion of social, primary, and recruitment biases raised against twin research methods follows.

1. *Classic Twin Study: MZ and DZ Twins Reared Together.* The classic twin method compares resemblance within MZ twin pairs to resemblance within DZ twin pairs. This method was first described by Sir Francis Galton, in England, in 1875. (The embryological bases of twinning were not established until the early 1900s, but Galton correctly postulated that there were twin pairs originating from one egg and twin pairs originating from two eggs.) The twin method assumes equal environmental influences for both types of twins. Greater resemblance within MZ twin pairs, relative to DZ twin pairs, is consistent with (although not proof of) a genetic explanation for the trait under investigation. Differences within MZ twin pairs are explained by environmental effects because all genetic inheritance is commonly shared. In contrast, differences within DZ twin pairs are associated with both genetic and environmental influences because these twins share half their genes, on average, by descent. This reasoning is the central common theme underlying the various twin methodologies.

2. *Cotwin Control Studies.* The method of cotwin control provides different treatments or training programs to each member of a monozygotic twinship (alternatively, treatment may be made available to only one twin), and the outcomes are later assessed. Variations in this method may be the provision of the same treatment to both twins, but at different times, to examine interactions between training and maturation. The best-known studies of this kind were those of Gesell and Thompson (1929, 1941), Hilgard (1933), and McGraw (1935), in which early training in mental and physical skills was provided to one member of a young MZ twin pair. (The twins in McGraw's study later proved to be DZ [Mittler, 1971].) Reappraisal of these classic studies has recently been undertaken by Raze1 (1985).

3. *Singleton Twins.* Twins whose cotwins have died at birth, or shortly thereafter, afford researchers a unique opportunity to study the developmental histories of singleton twins. These individuals are reared as nontwins, unaffected by the social-interactional aspects of twinship or by unusual treatment from others because they are twins. These individuals do, however, still claim the unique biology associated with multiple births. They, therefore, provide a meaningful backdrop against which to comparatively assess the social influences of twinship.

4. *Dizygotic Twin Designs.* Several investigators have tried to determine if increasing genetic relatedness in DZ twins is associated with increased behavioral and/or physical resemblance. Extensive analysis of the blood group characteristics of DZ twins and their families (Dumont-Driscoll & Rose, 1983) has yielded estimates of the proportion of genes identical by descent within these twinships. This index of biological similarity is imprecise but represents a significant first step toward addressing this interesting issue.

5. *Longitudinal Twin Studies.* Longitudinal studies sample behavior at selected periods during the course of development in an attempt to identify genetic and environmental influences associated with change. Longitudinal twin designs offer valuable opportunities to examine genetic influences on behavioral consistency, and on the timing and expression of behavioral and physical characteristics. This area of research is known as chronogenetics. Using both twins and their singleton siblings in longitudinal studies improves the efficiency of this particular design (cf. Wilson, 1983).

6. *The Twin-Family Design.* The family members of adult monozygotic twins are related to one another in unique fashion. The children of MZ twins, while biological first cousins, are also genetically equivalent to half-siblings because they share a genetically identical parent (twin mother or twin father). In addition to cotwin comparisons, behavioral similarity between spouses, siblings, and "half-siblings" can be examined. Maternal effects can be detected by comparing resemblance between half-siblings whose mothers are MZ twins and half-siblings whose fathers are MZ twins. A parallel version of the twin-family design has been used in animal research; its application for human studies is described by Scarr-Salapatek (1975).

7. *Twins as Couples.* The *couple effect* refers to the varying functional roles assumed by the members of MZ twinships because of their social interdependence (Zazzo, 1978). Fuller and Hahn (1976) asserted that genotypic effects on the social structure of members of inbred animal strains may be distinct from genotypic effects on individual behavior, an argument that is perfectly applicable to human behavior. Twins may perform differently when interacting with their cotwins, as compared with acting alone. Researchers interested in this aspect of twinship would sample twins' behaviors both alone and together, under standard conditions.

8. *Twins and Nontwins.* Comparisons between twins and nontwins across a range of behavioral and physical measures may highlight the effects of the unique biological and

psychological aspects of twinship. These comparisons also provide additional tests of the contribution of genetic and environmental influences to various traits. In some cases, investigators study the singleton siblings of twins, while in other cases they may include sibling pairs who are close in age, or pairs of unrelated, age-matched singletons.

9. *Partially Reared Apart Twins.* Partially reared apart twin designs involve comparison of twins who have lived apart for a number of years with twins who have always lived together. The aim of this design is to determine if a common environment significantly contributes to behavioral similarity or dissimilarity, and if this process functions equally for the two types of twins. Twins of various ages may be selected to determine if the living situation has a more important impact on resemblance during the early or later years.

10. *Twins Reared Apart.* Reared apart MZ twins constitute the most potent, naturally occurring research design for tests of genetic and environmental influences on behavior. If the twins are separated early in infancy and raised in uncorrelated trait-relevant environments, studies of reared apart MZ twins provide a direct estimate of genetic influences on behavior. The study of DZ twins reared apart enables critical tests of the hypothesis that similar rearing environments may be associated with behavioral resemblance. Comparison with twins reared together (twin/adoption design) provides information on the influence of common rearing on behavioral and physical similarity.

Studying reared apart twins offers other important advantages. It becomes possible to determine if specific differences in the rearing environments of these twins are associated with current behavioral or medical differences between them. It is possible, for example, to study the relationship between cotwin differences in educational advantage and IQ (Newman, Freeman, & Holzinger, 1937). Testing the adopted siblings of reared apart twins is a unique method of studying individuals who share environments but not genes; this is precisely the reverse of studying separated MZ twins.

Biases in Twin Research

Various challenges and criticisms have been raised against the classic twin method. Some of the variations on this design evolved in an attempt to circumvent some of these potential difficulties. The primary, social, and recruitment biases in twin research are briefly reviewed below. Empirical testing of some of these biases has shown that they do not jeopardize findings. In twin research, as in all domains of inquiry, replication of results based on varied samples and methodologies is a desirable goal.

Social Biases. The assumption of equal environments for MZ and DZ twin pairs is basic to the logic of the classic twin method. This assumption has met with considerable debate by some critics. It has been argued that individuals respond to the physical identity of MZ twins by encouraging, or creating, identical environments. DZ twins, in contrast, would experience less similar environments as they are not identical in appearance (Taylor 1980; Farber 1981). Such criticisms are testable. It must be demonstrated that the environmental or treatment variable on which the twins differ is, in fact, a variable that influences the trait in question (Bouchard, 1984). Furthermore, the direction of effect must be in the predicted direction (Bouchard & Segal, 1985). Several studies have found little effect on mental ability, personality, or interests from more similar environments or parental treatments of MZ than DZ twins (Scarr, 1969; Loehlin & Nichols, 1976; Plomin, Willerman, & Loehlin, 1976; Matheny, Wilson, & Dolan, 1976; Vandenberg & Wilson, 1979).

It is sometimes reasoned that MZ twins (primarily) strongly identify with one another (*assimilation*), thereby minimizing within-pair differences. In contrast, DZ twins are expected to show increasing differentiation (*contrast*). These effects, if real, would predict an excess of twin pairs with small differences and an excess of twin pairs with marked differences. There is, however, no empirical evidence of these effects (Loehlin & Nichols, 1976; Bouchard, 1984). A recent article by Plomin and Loehlin (1989) discussed these processes with respect to IQ similarity in MZ and DZ twin pairs.

Primary Biases. Primary biases refer to the "prenatal and natal environmental factors peculiar in kind or degree to twin studies" (Price, 1950). These factors (which mainly affect MZ twin pairs) include birth events, lateral inversions, and the effects of mutual circulation in utero. To the extent that these factors affect behavioral and physical development, they tend to make genetically identical cotwins less similar than expected: "In all probability the net effect of most twin studies has been underestimation of the significance of heredity in the medical and behavioral sciences" (Price, 1950). Studies directed toward resolving this question have yielded mixed findings (Wilson, 1979; Rose, Reed, & Bogle, 1987), such that the influence of primary biases in psychological research is currently unknown.

A caution to twin researchers is that classic twin methodology may not be appropriately applied if MZ twins are uniquely subject to prenatal events associated with the behavior of interest. The relationship between delayed zygotic splitting and discordance for handedness in approximately 25% of MZ twin pairs precludes use of the classic twin design for studying the origins of hand preference, because the assumption of equal environments for both types of twins is violated.

Recruitment Biases. In studies using adult same-sex twins, approximately two-thirds of volunteer twin pairs are female, and two-thirds are MZ (Lykken, McGue, & Tellegen, 1987). An excess of MZ twin pairs has also been found in research using twin children, in which families were contacted primarily through twins clubs and personal referrals (Segal, 1985). Such recruitment bias suggests that available male and DZ twin pairs may show reduced within-pair differences on some characteristics. Consequences of such bias may include overestimation of the true twin correlations and twin group differences in the total variance of a trait (Lykken et al., 1987). Ascertainment of twins by means of population registries may help to mitigate this source of bias. Tambs, Sundet, Magnus, and Berg (1989), however, demonstrated an absence of recruitment bias for questionnaire data which are highly correlated with IQ.

SUMMARY OF FINDINGS FROM TWIN RESEARCH

Twin studies have contributed to knowledge in many behavioral and medical domains. A selective sampling of findings from twin research in learning disabilities, personality and temperament, attitudes, psychopathology, and social behavior are summarized in the following sections. Although general intelligence and specific cognitive abilities have received far greater attention than other behavioral domains, these studies are not reviewed here since there are numerous excellent reviews available (e.g., Bouchard & McGue, 1981; Plomin et al., 1990). Rather, this article will focus on social and abnormal domains of psychological functioning.

Learning Disabilities

Results from twin analyses may suggest important implications for the etiology of learning disorders among the nontwin population. A review of the twin literature on spelling disorders is presented below; twin studies of reading disabilities are presented elsewhere in this special feature (see LaBuda, DeFries, and Pennington, page 645).

Spelling. Little individual difference research on spelling ability has been conducted using twin methodology. Stevenson, Graham, Fredman, and McLoughlin (1987) reported substantial genetic influence on *spelling backwardness* (spelling age below chronological age) and *spelling retardation* (underachievement in spelling in relation to that predicted from IQ and chronological age), as measured by the Schonell Spelling Test. Intraclass correlations for spelling age were .76 for MZ twin pairs and .50 for DZ twin pairs; IQ-adjusted intraclass correlations were .75 for MZ twin pairs and .39 for DZ twin pairs. Risk of spelling retardation to the cotwin of an affected MZ twin was higher than that for an affected DZ twin across all levels of severity. The number of twins was, however, small in the most severe ranges. Lytton, Watts, and Dunn (1988) administered the Peabody Individual Achievement Test (PIAT) to MZ and DZ twins pairs at 9 years of age. The spelling test measure from this battery demonstrated a significant genetic component, as indicated by intraclass correlations of .81 for MZ twin pairs and .24 for DZ twin pairs.

The literature on MZ twins reared apart includes several pairs in which specific reading and spelling disabilities were observed. Both twins in one pair demonstrated dyslexia, in addition to psychotic symptoms. In another case, both male twins were poor spellers and transposed letters. In a third case, both female twins experienced difficulty at school, and one twin did not learn to read until adulthood. It is additionally interesting that all four children of one of the twins and one child (daughter) of the cotwin displayed reading disabilities. The Minnesota Study of Twins Reared Apart, at the University of Minnesota, is currently administering reading and spelling tests to MZ and DZ twins, their adoptive siblings and spouses. This is the only systematically conducted study of reading and spelling skills in reared apart twins.

The average intellectual deficit observed among twins is often attributed to unique aspects of their language development (e.g., immature speech arising from a reduced need to communicate with the twin partner in some cases [Lytton, Conway, & Sauvé, 1977]). Suggested readings comparing cognitive abilities in twins and nontwins include Day (1932), Koch (1966), Lytton (1980), Savić (1980), and Hay, Prior, Collett, and O'Brian (1987). Studies using twins to study various other learning disabilities and disorders are also available (Willerman, 1973; Bakwin, 1973).

Personality and Temperament

Twins have been used to evaluate genetic and environmental influences on a variety of personality characteristics. Several key twin studies and position papers have substantially influenced the course of research in this area, and they are the focus of this review.

A landmark twin study of personality included 850 pairs of high school age twins, identified by having taken the National Merit Scholarship Qualifying Test (Loehlin & Nichols, 1976). Participants completed the California Personality Inventory (CPI), which includes 19 personality scales (e.g., dominance, sociability, and tolerance). The median correlation for MZ twin pairs was about .50 and the median correlation for DZ twin pairs was about .30. A comprehensive survey of 106 twin studies of nine personality traits by Nichols (1978) reported median intraclass correlations of .48 for MZ twin pairs and .23 for DZ twin pairs. The correlations ranged between .37 and .53 for the MZ twin pairs and between. 17 and .31 for the DZ twin pairs. Similar results are reported in reviews by Goldsmith (1983) and by Plomin and Daniels (1987).

Doubling the difference between the MZ and DZ twin correlations provides an estimate of heritability, or the proportion of trait variance associated with genetic influences. The majority of twin studies of personality suggest that 50% of the variance is associated with genetic influences, while the remaining 50% is associated with environmental effects.

The finding of more similar environments for MZ twins than DZ twins has been raised as a possible social bias, as indicated earlier. This bias has, however, largely been refuted. Loehlin and Nichols (1976) did not find meaningful associations between cotwin differences in personality and cotwin differences in environmental variables. Matheny, Wilson, and Dolan (1976) and Plomin, Willerman, and Loehlin (1976) did not find correlations between physical and behavioral resemblance in MZ twin pairs. In fact, Plomin et al. (1976) found that the most frequently confused MZ twins were rated by parents as least similar in behavior. These analyses and others support a genetic interpretation of MZ cotwin similarity, implying genetic influences on personality.

Social biases in twin research are resolved, in large part, by studies of twins raised separately. Data on neuroticism and extraversion in previous studies of MZ twins reared apart (MZA) are summarized in Bouchard (1984). Intraclass correlations for neuroticism were .53 and .58 in studies by Shields (1962) and Newman et al. (1937). A .61 correlation for extraversion was reported by Shields (1962). These investigators also collected data on twins reared together. MZ twins reared together (MZT) provide informative contrasts for these analyses, as they reveal the contribution of the shared environment to personality similarity. Intraclass correlations of .38 (Shields, 1962) and .56 (Newman et al., 1937) for neuroticism and .42 for extraversion (Shields, 1962) for MZ twins reared together were reported. Twins reared apart and together were equally similar in the Newman et al. (1937) study, but twins reared apart were *more* similar than twins reared together in the Shields (1962) study. It has been suggested that twins reared together may "create" differences between themselves in an attempt at differentiation from the twin. Canter (1973) observed that both types of twins (but especially MZ twins) living together were less alike in extraversion than twins who had been living apart for 5 years. This phenomenon does not, however, replicate across samples or across personality traits (Wilde, 1974).

Recent studies which include MZ and DZ twins reared together and apart (twin/adoption design) found that the two MZ twin groups are equally similar in personality. Tellegen, Lykken, Bouchard, Wilcox, Segal, and Rich (1988) administered the Minnesota Multiphasic Personality Questionnaire (MPQ) to 217 MZ and 114 DZ twin pairs reared together (mean ages 23.5 and 19.8 years) and to 44 MZ and 27 DZ twin pairs reared apart (mean ages 40.7 and 41.1 years). The MPQ includes 11 personality scales and 3 higher-order scales. The median intraclass correlations were .49 and .52 for MZA and MZT twin pairs, respectively, suggesting that a common family environment has little effect on personality resemblance. This does not mean that personality is unaffected by environmental effects; rather,

the remaining 50% of the variance is associated with environmental factors unique to the individual and measurement error.

Pedersen, Plomin, McClearn, and Friberg (1988) compared similarity in neuroticism, extraversion, and related traits in Swedish adult twins reared apart and reared together. The mean age of the sample was 58.6 years. Twins completed a short form of the Eysenck Personality Inventory (EPI) to measure extraversion and neuroticism and the impulsivity and monotony avoidance scales from the Karolinska Scales of Personality. Genetic factors contributed to similarity on all four personality traits, explaining between 23% to 45% of the variance. Heritability for monotony avoidance (.23) was, however, less than expected on the basis of previous studies. Pedersen et al. (1988) suggested that genetic factors may be less influential on selected aspects of personality during later stages of the life span but noted that longitudinal analyses are needed to resolve this issue. Finally, the shared environment had a negligible effect on personality resemblance. A study of Finnish twins reared apart and together by Langinvainio, Kaprio, Koskenvuo, and Lönnqvist (1984) also found a negligible effect of the shared environment on resemblance in extraversion and neuroticism. Pedersen et al. (1988) noted that estimates of genetic influence on extraversion (.34) and neuroticism (.27) from the Finnish study were lower than values reported for twins reared together.

Loehlin et al. (1976) suggested that different personality traits are not differentially influenced by genetic factors. Tellegen et al. (1988) found some evidence of differential heritability among traits measured by the MPQ, an instrument composed of highly independent scales. Comparable heritability for some personality measures was also found. It has been argued that item overlap among personality scales may explain the absence of differential heritability reported in some studies (Horn, Plomin, & Rosenman, 1976). Tellegen et al. (1988) also noted that heritability estimates may vary as a function of the genetic model fit to the data. The controversy surrounding the differential heritability of personality traits is further elaborated by these investigators, and by Plomin (1986).

Individual differences in temperamental characteristics are of great interest to psychologists (Rothbart & Derryberry, 1981). Temperament refers to stylistic aspects of behavior (i.e., "how" behavior is expressed) rather than its content (i.e., "what" behavior is expressed) (Buss & Plomin, 1984). Most temperament researchers have studied twin infants or children (Freedman & Keller, 1963; Buss & Plomin, 1975; Stevenson & Fielding, 1985; Wilson & Matheny, 1986), although a recent article reported findings for adult MZ and DZ twins reared together and apart (Plomin, Pedersen, McClearn, Nesselrode, & Bergeman, 1988). Parental ratings and interviews are used more often than observational techniques, which yield greater evidence for differential heritability than self-report methods or ratings (Buss & Plomin, 1986).

Two temperament schemes have frequently been used in studies of twins. The first scheme, developed by Thomas, Chess, and Birch (1968), includes nine temperamental categories: rhythmicity, threshold, approach, intensity, activity, persistence, distractibility, mood, and adaptability. Torgersen and Kringlen (1978) found that MZ twins were more similar than DZ twins on all nine variables, at ages 2 and 9 months. Mothers' perceptions of degree of physical resemblance were unrelated to their temperament ratings. A follow-up study at age 6 years showed that MZ twins were more alike than DZ twins on eight variables (distractibility ratings could not be reliably made), especially on activity, approach-withdrawal, intensity, and attention span (Torgersen, 1981). It was noted that regularity, adaptability, and mood, which showed the least evidence of genetic effects, have been identified as risk factors for behavioral disorder. Follow-up at age 15 indicated greater MZ twin similarity than in earlier years (Torgersen, 1987). A second temperament scheme developed by Buss and Plomin (1975) included four temperaments: emotionality, activity, sociability, and impulsivity (EASI). Parents completed the 20-item EASI Temperament Survey for 38 MZ male twin pairs, 43 MZ female twin pairs, 33 DZ male twin pairs, and 24 DZ female twin pairs. Evidence of genetic influence was found for all temperaments except impulsivity, for which a genetic effect was detected for male twins, but not for female twins. Stevenson and Fielding (1985) obtained EASI temperament ratings on 576 twin pairs in three age groups: 0-2 years; 2-5 years; and 5+ years. Evidence of genetic influences on emotionality and sociability were found for female twins, but not for male twins. Activity showed increasing genetic influence with increases in age for both male and female twins, while impulsivity did not show substantial genetic influence at any age. Impulsivity has been omitted from the original scheme, given its failure to fulfill a major criteria (inheritance) for qualifying as a temperament (Buss & Plomin, 1986).

Plomin et al. (1988) administered the EASI Temperament Survey to 99 MZ and 229 DZ twin pairs reared apart and to 160 MZ and 212 DZ twin pairs reared together. The mean age of the sample was 59 years. Unlike the 1975 version, this survey included five scales; emotionality was presented as emotionality-distress, emotionality-fear, and emotionality-anger. Heritabilities were estimated as falling between .20 and .40, values lower than those based upon younger samples. The shared environment and effects from selective placement contributed little to the variance of these measures.

The majority of twin studies of personality and temperament converge on the common themes that (1) genetic factors substantially influence these behaviors, and that (2) the important environmental effects are those that are nonshared. Studies of older twin populations are clearly needed. Longitudinal study of participants in the Minnesota Study of Twins Reared Apart is now in progress and should begin to fill this gap in the future. Other studies concerned with the effects of shared environment on personality similarity in twins include Rose and Kaprio (1988) and references therein. Additional studies and reviews of the twin literature on personality and temperament may be found in Goldsmith (1983), Plomin (1986), Plomin and Dunn (1986) and Matheny (1987).

Attitudes

Twin studies have recently begun to contribute to our understanding of attitudes. Two areas that have been the focus of recent attention are reviewed in the following sections.

Social Attitudes. Recent twin studies have challenged the view that cultural inheritance is chiefly responsible for familial resemblance in social attitudes. This challenge derives from the fact that studies of intact biological families cannot resolve the sources of resemblance into genetic or environmental components. Martin, Eaves, Heath, Jardine, Feingold, and Eysenck (1986) obtained social attitude questionnaires from 3,810 Australian twin pairs and 825 British twin pairs. Data were also available for 103 Australian spouse pairs and 562 British spouse pairs. Spouses of twins can further examine questions concerning similarity in social attitudes by comparing resemblance

between the spouse and twin, the spouse and cotwin, and the two spouses of each cotwin.

The Australian twins completed the 50-item Wilson-Patterson conservatism scale. Participants were asked if they agreed, or disagreed, with each item listed, and a conservatism score was then derived from a weighting of items. Fourteen items (e.g., socialism and church authority) gave evidence of significant genetic and social influence. Nineteen items (e.g., death penalty and self-denial) provided evidence of significant genetic influence without social influence. Fourteen items (e.g., chastity and birth control) gave evidence of sex differences in genetic and environmental effects. Only three items (co-education, straitjackets, and pajama parties) demonstrated significant social transmission and an absence of genetic influence. Twin resemblance for the conservatism score was higher for male and female MZ twin pairs (MZm r=.60; MZf r= .64) than for male and female DZ twin pairs (DZm r= .47; DZf r= .46), or opposite-sex twin pairs (DZos r= .41).

The British twins completed a 40-item Public Opinion Survey, on which they rated agreement with each statement on a 5-point scale. Two factors—radicalism ("left versus right" dimension in British politics) and toughmindedness (approval of capital and corporal punishment)—were derived. Age-corrected correlations for radicalism were higher for male and female MZ twin pairs (MZm r = .75; MZf r = .60) than for male and female DZ twin pairs (DZm r = .52; DZf r= .51), or opposite-sex twin pairs (DZos r = .48). Similarly, twin resemblance for toughmindedness was higher for male and female MZ twin pairs (MZm r= .49; MZf r= .69) than for male and female DZ twin pairs (DZm r = .18; DZf r = .41), or opposite-sex twin pairs (DZos r= .28). Sex differences in cultural and genetic influences on radicalism and toughmindedness are suggested by differences in the magnitudes of these correlations. An earlier twin study using the Public Opinion Survey also reported genetic influences on these measures (Eaves & Eysenck, 1974).

Tellegen et al. (1988) reported a significant genetic contribution to the traditionalism scale. Individuals high in traditionalism, as assessed by the MPQ, endorse high moral standards, support religious values, and dislike permissiveness. Individuals low in traditionalism challenge established authority, consider traditional values outdated, and value rebelliousness and freedom of expression.

The studies reviewed in the preceding paragraphs are provocative, in that by demonstrating genetic influence on the transmission of social attitudes, traditional environmental explanations are for the first time put to test. Replication of such research is clearly needed. The Public Opinion Survey, as well as other attitude and interest inventories (e.g., Strong-Campbell Interest Inventory and the Jackson Vocational Interest Survey), are currently being completed by participants (twins and spouses) in the Minnesota Study of Twins Reared Apart. The availability of data on varied kinship pairings will provide stringent tests of the findings of Martin et al. (1986).

Job Satisfaction. Job satisfaction has multiple determinants (Locke, 1976), suggesting that some aspects of job satisfaction may be influenced by genetic factors. Participants in the Minnesota Study of Twins Reared Apart completed the short form of the Minnesota Job Satisfaction Questionnaire (MJSQ), on which satisfaction with 20 job-related items is rated on a 5-point scale. An analysis of 34 pairs of MZ twins raised separately was reported by Arvey, Bouchard, Segal, and Abraham, (1989). Intraclass correlations of .32 and .31 for intrinsic job satisfaction (e.g., ability utilization and achievement) and general job satisfaction (summation of the 20 items) were found. A genetic influence on these aspects of job satisfaction is, thus, demonstrated, although the majority of variance is associated with environmental factors. Evidence of genetic influence was not detected for extrinsic job satisfaction (e.g., company policies and working conditions) or for overall job satisfaction (as measured by a single item).

Intraclass correlations for complexity, motor skill requirements, and physical demands of the twins' jobs were significant. Cotwin similarity for the extrinsic and general satisfaction scales was not reduced after controlling for these variables, further supporting a genetic influence on these facets of job satisfaction. The intraclass correlation for work conditions, in contrast, failed to reach statistical significance. The investigators speculated that the genetic influence on job satisfaction may have reflected various personality factors (e.g., positive affect or negative affect), which have demonstrated heritability. Longitudinal designs for examining job performance and job satisfaction in varying environments were proposed.

A distinguishing feature of the study by Arvey et al. (1989) was its use of twins for studying organizationally based phenomena. A summary of twin studies of vocational interests may be found in Fuller and Thompson (1978) and Nichols (1978).

Behavioral Disorders

Twin studies of the major psychoses reveal that both genetic and environmental influences underlie these disorders. The MZ and DZ twin (probandwise) concordance figures for schizophrenia are 46% and 14% (Gottesman & Shields, 1982). The MZ and DZ twin (pairwise) concordance figures for bipolar depressive illness are 50% and 15% (Kringlen, 1985). Twin studies of both schizophrenia and manic-depressive illness have been widely reviewed (Gottesman & Shields, 1982; Kendler, 1983; Kringlen, 1985; Farmer, McGuffin, & Gottesman, 1987), as have twin studies of alcoholism (Kaprio, Koskenvuo, Langinvainio, Romanov, Sarna, & Rose, 1987) and antisocial behavior (Rowe, 1986; Rowe & Rodgers, 1989; see also Raine & Dunkin in this special feature). The majority of these studies provide support for both genetic and environmental influences on these behaviors. A summary of selected behavioral disorders that have been less frequently examined from a twin research perspective will be presented. (Although the role of genetic factors in Alzheimer's Disease has received considerable attention in recent years, these studies will not be reviewed here because they are covered by Gatz in this special feature.)

Obsessive-Compulsive Disorder. Interest in a possible genetic influence on Obsessive-Compulsive Disorder (OCD) has prevailed, despite widespread belief in a psychogenic etiology (Hoaken & Schnurr, 1980). *Obsessions* refer to persistent ideas, thoughts, and images, while *compulsions* refer to repetitive, seemingly purposeful behavior expressed in stereotypic fashion. The infrequency of OCD in the population, plus the rarity of MZ twinning (1/240 births) may explain the relative lack of twin research on this disorder. McGuffin and Mawson (1980) estimated that the probability of finding an MZ twin pair concordant for OCD is 1/6-800 million. There is, nevertheless, a small body of twin studies that suggest genetic influences on OCD. A review of 15 early studies and case reports by Inouye (1972) reported concordance among 77% (27/35) MZ twin pairs and (0/7) DZ twin pairs. Carey and Gottesman (1981) noted, however, that many early studies suffer from inadequate sampling procedures and methods for establishing zygosity. Other methodological difficulties include failure to distinguish among

obsessive-compulsive neurosis, mixed neurosis, and obsessive-compulsive personality (Hoaken & Schnurr, 1980).

A recent twin study and several case reports are informative. Carey and Gottesman (1981) examined a consecutively sampled series of twins admitted to one of two British hospitals between 1948–1972, who were diagnosed with obsessional neurosis, obsessional personality, or phobic neurosis. Preliminary data were reported for 49 out of 60 registered twin pairs, of which 15 MZ and 15 DZ twin pairs displayed obsessive behaviors. Concordance for obsessive features was found for 87% of the MZ twin pairs and 47% of the DZ twin pairs, suggesting genetic influences. This twin group difference, while substantial, is based on a modest size sample, so that additional cases are needed. Mean Minnesota Multiphasic Personality Profiles (MMPIs) revealed characteristic obsessive-compulsive concerns. Profile patterns were parallel for MZ cotwins and somewhat similar for DZ cotwins, also suggesting genetic transmission.

McGuffin and Mawson (1980) reported two MZ female twin pairs, both of whom were concordant for obsessive-compulsive neurosis. Social biases have, however, been raised as a possible challenge to genetic explanations of behavioral similarity in MZ cotwins. Concordance for symptoms in twin pairs who have experienced little social contact would, however, provide persuasive evidence of a genetic contribution. A striking feature of this particular case report is that the cotwins in both pairs had developed their symptoms without knowledge of illness in the twin sister. The literature on twins reared apart also includes one MZ twin pair and two DZ twin pairs concordant for obsessive-compulsive symptoms (Carey & Gottesman, 1981). These cases, while informative, are few in number. A second recent case study reported discordance in a pair of MZ female twins, possibly associated with difficulty in coping with anger and assertiveness in one twin.

The nature of the genetic factor possibly associated with obsessive-compulsive behavior remains at issue. McGuffin and Mawson (1980) suggested that, as in other psychiatric disorders, multiple genes and multiple environmental factors may be implicated. Some individuals may have a genetically influenced liability for the disorder, expressed when the liability exceeds a certain threshold level. Twin studies, especially longitudinal follow-up studies of affected twins, should further understanding of the etiology of obsessive-compulsive behavior.

Anorexia Nervosa. Anorexia nervosa is an eating disorder most commonly affecting young women. The major identifying features condition include self-induced weight loss and consequent amenorrhea. Anorexia nervosa seems to occur with equal frequency among twins and nontwins (Holland, Hall, Murray, Russell, & Crisp, 1984).

Holland et al. (1984) asserted that "a genetic vulnerability might be a predisposition to a particular personality type, to psychiatric illness in general (and in particular affective disorder), to a disturbance of body image, or to a hypothalamic disorder. Thus [MZ] twins carrying one or more vulnerability factors would both have the potential for developing anorexia nervosa under conditions of stress. Other factors such as earlier life experiences or particular life events may be different in each of the twins, thus influencing the expression of the disorder" (p. 417). Crisp, Hall, and Holland (1985) similarly acknowledged the joint importance of genetic factors and developmental experiences in the onset of anorectic episodes.

Psychological aspects of twinship may uniquely influence anorexia nervosa in twins. *Induction* has been proposed to explain the greater MZ than DZ twin resemblance. During adolescence, MZ twins (who are very close and have been treated as a unit) may confront challenges associated with separation that are *not* experienced by DZ twins. The development of anorexia may work to minimize differences, thereby counteracting separation. Induction would not be operative, however, in families that exaggerated slight differences between MZ cotwins (Holland et al., 1984). Stress, coupled with a predisposed genotype, may be implicated in some forms of this disorder.

Holland et al. (1984) observed concordance in 9 out of 16 MZ twin pairs, and in only 1 out of 14 DZ twin pairs. Association between anorexia and birth order, birth weight, or educational success were not observed among discordant twin pairs. Birth difficulties were identified in seven discordant twin pairs: in five cases these difficulties generally affected the ill twins, and in two cases they affected both twins. Holland et al. (1984) noted that these relationships were suggestive but warned that they were based on modest size samples. In a further analysis of these same twins, Crisp et al. (1985) reported that, in concordant MZ twin pairs, the age of onset for twins who first become ill (mean age = 15 years) was much younger than for their ill twin partners (mean age = 17.3 years). These twins also developed anorexia nervosa earlier than anorectic identical twins with nonanorectic twin partners (17.6 years), anorectic fraternal twins with nonanorectic twin partners (17.9 years), and anorectic individuals in the general population (17.6 years). (Twins in the single similar fraternal pair developed the disorder at ages 15 and 17.) It was suggested that this might reflect the "special vulnerability of identical twins when faced with puberty."

The few available twin studies of anorexia reported greater resemblance between MZ twins than between DZ twins, thus supporting (although not proving) genetic effects. Environmental influences are indicated by the finding that not all affected MZ twins have affected cotwins, and that concordant MZ twins may show variable symptom expression (Suematsu, Kuboki, & Ogata, 1986). The complex psychological and social factors that have been associated with anorexia nervosa are very important to appreciate (see Bruch, 1988). Bank and Kahn (1982) described the life history events linked to anorexia nervosa in one member of an female MZ twin pair; such cases may have implications for near-in-age siblings. The origins of anorexia nervosa are clearly unresolved, but twin studies are suggesting some promising leads.

Tourette's Disorder. Tourette's Disorder (TD) is a neuropsychiatric disorder, chiefly characterized by involuntary motor and vocal tics. The disorder begins between 2 and 15 years of age and often appears first as eye blinking. Males are three times as likely as females to be affected.

The majority of twin research on TD includes single case histories or reviews of multiple case histories (Jenkins & Ashby, 1983; Waserman, Lal, & Gauthier, 1983; Vieregge, Schäfer & Jörg, 1988; Segal, Dysken, Bouchard, Pedersen, Eckert, & Heston, 1990; see also Price, Kidd, Cohen, Pauls, & Leckman, 1985). Reports of greater resemblance between identical twins than fraternal twins are consistent with a genetic influence on TD. Case studies, while informative, were not systematically ascertained. Furthermore, concordant twin pairs may be more likely to receive medical attention than discordant twin pairs (Jenkins & Ashby, 1983).

Using strict diagnostic criteria, the only systematically conducted twin study of TD reported concordance figures of 53% for MZ twin pairs and 8% for DZ twin pairs (Price, Kidd, Cohen, Pauls, & Leckman, 1985). When the diagnostic criteria were broadened to include "any tics" in the twin partners, concor-

dance figures rose to 77% for MZ twin pairs and 23% for DZ twin pairs. Substantial genetic influence on the development of TD was supported, although the authors suggested that unknown nongenetic factors (i.e., environmental exposures or periods of enhanced vulnerability during development) may influence the onset and expression of TD.

Social Behavior

Comparative analyses of the social relationships shared by MZ and DZ twin pairs may enhance understanding of the quality of social relationships shared by other pairs of relatives. Most research on twin relationships has used interviews and questionnaires. Several studies have, however, applied experimental methods in seminaturalistic settings.

Social Relationships. An impressive body of experimental, clinical, and observational data suggests that MZ twins share a more intimate social bond, relative to DZ twins (Burlingham, 1952; Mowrer, 1954; Parker, 1964; Smith, Renshaw, & Renshaw 1968; Loehlin & Nichols, 1976; Paluszny, Selzer, Vinokur, & Lewandowski, 1977; Segal, 1984b). Psychodynamic interpretations of this phenomenon refer to the similar physical appearance and rearing life histories of MZ twins (Joseph & Tabor, 1961; Siemon, 1980). An alternative explanation, grounded in social genetic theory, would consider the relative genetic commonality of the interactants as influencing social behavior (Scott, 1983). This perspective recalls the *twins as couples t* design described previously.

Several studies have tested the hypothesis that social-interactional processes and outcomes may differ between genetically identical individuals (MZ twin pairs) and genetically nonidentical individuals (DZ twin pairs). Von Bracken (1934) demonstrated that young MZ twins tended to maintain equality during work activities performed in the company of the cotwin. DZ twins, in contrast, either behaved competitively (if matched in skill) or disinterestedly (if unmatched in skill). Segal (1984b) found that young MZ twin pairs were more successful at puzzle completion than DZ twin pairs. Comparative examination of social behaviors displayed during this task (e.g., proportion of time puzzle remained equidistant between twins; rate of passive physical gesturing) suggested greater cooperation within MZ twinships than within DZ twinships. The mechanisms underlying these twin group differences are not yet clear but may be associated with the greater average similarity in cognition, personality, and behavioral style of MZ twins than DZ twins. Additional studies of twins as social units may help to identify behavioral characteristics associated with cooperative and competitive social exchange between cotwins and between other interactants.

Bereavement Research. Individual differences in response to bereavement are becoming increasingly appreciated by psychological researchers and counselors (Osterweis, Solomon, & Green, 1984). Frequently studied variables along which individuals have been shown to vary include age, sex, and marital status. Several studies have also implicated the relatedness of the deceased to the survivor as a factor influencing bereavement processes. The majority of studies find that the death of a child is the most devastating and enduring form of loss (Sanders, 1989). Based on responses to the Grief Experience Inventory (GEI) (Sanders, Mauger, & Strong, 1977), Sanders (1979–1980) observed that the loss of a child is experienced more intensely than the loss of a parent or spouse. Grief ratings were based on a 7-point scale (1 = *No Grief* to 7 = *Total Devastation; Suicide Point),* as experienced 1–2 months following the death. An analysis of parental grief intensity, also using the GEI, reported that parents grieved significantly more for children whom they perceived as resembling their family more than their spouse's family (Littlefield & Rushton, 1986).

Bereavement studies of MZ and DZ twins can address the questions: Is twin loss more severe to the twin than the loss of other relatives? Is the loss of an MZ twin more devastating than the loss of a DZ twin? Answers to these questions can potentially clarify the grief experiences of individuals of varying degrees of genetic relatedness to the deceased. Mowrer (1954) asked high school age twins to name the family member who would be missed most in the event of death. Mothers were selected most often, with the twin chosen as a close second, and the father as a distant third. These results were, unfortunately, not presented by twin type. (Preference for the twin was, nevertheless, twice as great among MZ twins than among DZ twins.) In this study, however, twins were not providing responses to an *actual* death, but to a *hypothetical* death. A later study of twin loss in adulthood was reported by Woodward (1987, and personal communication, November 1989). Her sample of 219 bereaved twins included 90 MZ twins, 42 same-sex DZ twins, 69 opposite-sex DZ twins, and 18 twins who were not classifiable. (The methods by which twin type was determined are, unfortunately, not documented in these two studies.) Ages of the surviving twins were 18 years and older. Twins rated the experience of twin loss as *severe, marked,* or *slight* during personal interviews. It was found that 42% chose severe, 39% chose marked, while only 19% chose slight. Death of the twin was experienced more intensely by surviving MZ twins than by surviving DZ twins: 57% of MZ twins and 35% of DZ twins rated twin loss as severe.

An informative essay on the MZ twin relationship and the experience of loss has been prepared by Engel (1975). A discussion of support services for parents who have lost a twin infant is found in Bryan (1986).

TWIN RESEARCH: IMPLICATIONS FOR MENTAL HEALTH PRACTICE

An individual differences approach to human behavior attempts to identify sources of similarity and diversity among people. Rooted in a biological tradition, both genetic and environmental influences are acknowledged as factors underlying behavioral and medical characteristics. Twin designs, when used creatively, help to highlight processes relevant to many aspects of human behavior.

The addition of an individual differences perspective to mental health research programs and practice may suggest alternative interpretations of observations. The following hypothetical example is illustrative: A set of parents is concerned that their adoptive child is displaying involuntary motor tics and other nervous mannerisms. This behavior is seriously interfering with school performance. The difficulty has been diagnosed as Tourette's Disorder (TD). The parents blame themselves and each other for this problem, leading to marital disharmony and tension in the home. Knowledge that TD may be genetically influenced can help mental health practitioners dispel parental guilt, as well as foster greater understanding and acceptance of the condition. This example similarly applies to families whose adoptive children show learning disabilities, fears and phobias, or other behavioral difficulties. Intact biological families may experience comparable situations: The pattern of genetic transmission of these disorders is unknown, such that one child may be affected while siblings may be unaffected. Awareness of a

possible genetic etiology may help to accurately assign causation, as well as to preserve domestic harmony.

It is important to emphasize that research findings based on large numbers of subjects may not apply at the level of the individual. Idiosyncratic life history events may prove critical in specific cases and should be considered in an evaluation. Findings from twin studies and other individual differences research can, however, provide a rich source of hypotheses.

A second potential benefit of an individual differences approach is the establishment of more effective treatments and interventions than are currently available. For example, individuals in a family who may be at risk for a learning disability, due to its presence among relatives, can be carefully observed; remedial measures may be promptly applied following detection of symptoms. This example is also relevant to the behavioral disorders reviewed in the previous section. Knowledge that behavioral and medical characteristics may have multiple etiologies should encourage fruitful consultation and collaboration between mental health practitioners and other psychological and medical professionals.

Summary

In sum, twin studies suggest that behavior in virtually every domain is influenced by genetic factors. Genetic influence does not imply, however, that behavior cannot be modified (Weinberg, 1989). Environmental factors also influence all forms of behavioral expression, and their impact seems to vary as a function of the specific behavior. The recent finding that nonshared, rather than shared, environmental factors underlie much of the environmental variance in personality, psychopathology, and cognition (Plomin & Daniels, 1987; Plomin, 1989) promises to substantially influence current theory and practice regarding human development. These concepts translate into renewed respect and appreciation for individual differences in behavior.

RESOURCES

A number of excellent resources are available to psychologists, educators, and mental health professionals who work with twins. There are, in addition, organizations and publications specifically designed to meet the unique needs of twins and parents of twins.

International Society for Twin Studies, The Mendel Institute, Piazza Galeno 5, 00161, Rome, Italy.

The Twins Foundation, P.O. Box 9487, Providence, RI 02940-9487, (401)274-TWIN.

Center for the Study of Multiple Birth, 333 East Superior Street, Suite 476, Chicago, IL 60611, (312)266-9093.

Multiple Births Foundation, Queen Charlotte's and Chelsea Hospital, Goldhawk Road, London W6 0XG, England (44-01), 748 4666, Ext. 5201.

Twins Magazine, P.O. Box 12045, Overland Park, KS 66212, (913)722-1090.

Twin Services, 400 Evelyn Avenue, Suite 222, El Cerrito Plaza Professional Building, Albany, CA 94706, (415)524-0863.

National Organization of Mothers of Twins Clubs (NOMOTC), 12404 Princess Jeanne NE, Albuquerque, NM 87112-4640, (505)275-0955. (Includes Cope/Outreach Department for twin loss)

International Twins Association, Lori Stewart, 6898 Channel Road NE, Minneapolis, MN 55432, (612)571-3022.

Our Newsletter (Support group for parents who have lost a twin child), Jean Kollantai, P. O. Box 1064, Palmer, AK 99645, (907)745-2706.

REFERENCES

Arvey, R. D., Bouchard, T. J., Jr., Segal, N. L., & Abraham, L. M. (1989). Job satisfaction: Environmental and genetic components. *Journal of Applied Psychology, 74,* 187-192.

Bakwin, H. (1973). Reading disability in twins. *Developmental Medicine and Child Neurology, 15,* 184-187.

Bank, S. P., & Kahn, M. D. *The sibling bond.* New York: Basic Books.

Bouchard, T. J., Jr. (1984). Twins reared apart and together: What they tell us about human diversity. In S. Fox (Ed.), *The chemical and biological bases of individualty* (pp. 147-184). New York: Plenum.

Bouchard, T. J., Jr., & McGue, M. (1981). Familial studies of intelligence. *Science, 212,* 1055-1059.

Bouchard, T. J., Jr., & Segal, N. L. (1985). IQ and environment. In B. B. Wolman (Ed.), *Handbook of intelligence* (pp. 391-464). New York: Wiley.

Bruch, H. (1988). *Conversations with anorexics.* D. Czyewski & M. A. Suhr (Eds.). New York: Basic Books.

Bryan, E. M. (1983). *The nature and nurture of twins.* London: Baillière Tindall.

Bryan, E. M. (1986). The death of a newborn twin: How can support for parents be improved? *Acta Geneticae Medicae et Gemellologiae, 35,* 115-118.

Buckler, J. M. H., & Robinson, A. (1974). Matched development of a pair of monozygotic twins of grossly different size at birth. *Archives of Diseases in Childhood, 49,* 472-476.

Bulmer, M. G. (1970). *The biology of twinning in man.* Oxford, England: Clarendon Press.

Burlingham, D. T. (1952). *Twins: A study of three identical pairs.* New York: International Universities Press.

Buss, A. H., & Plomin, R. (1975). *A temperament theory of personality development.* New York: Wiley-Interscience.

Buss, A. H., & Plomin, R. (1984). *Temperament: Early developing personality traits.* Hillsdale, NJ: Erlbaum.

Buss, A. H., & Plomin, R. (1986). The EAS approach to temperament. In R. Plomin & J. Dunn (Eds.), *The study of temperament: Changes, continuities and challenges* (pp. 67-79). Hillsdale, NJ: Erlbaum.

Canter, S. (1973). Personality traits in twins. In G. Claridge, S. Canter, & W. I. Hume, (Eds.), *Personality differences and biological variations: A study of twins.* Oxford, England: Pergamon.

Carey, G., & Gottesman, I. I. (1981). Twin and family studies of anxiety, phobic and obsessive disorders. In D. F. Klein & J. Rabkin (Eds.), *Anxiety: New research and changing concepts* (pp. 117-136). New York: Raven Press.

Carter-Saltzman, L. (1979). Mirror-twinning: Reflection of a genetically mediated embryological event? *Behavior Genetics, 9,* 442-443.

Clark, P., & Martin, N. G. (1982). An excess of the Pi^s allele in dizygotic twins and their mothers. *Human Genetics, 61,* 171-174.

Corney, G., Seedburgh, D., Thompson, B., Campbell, D. M., MacGillivray, I., & Timlin, D. (1981). Multiple and singleton pregnancy: Differences between mothers as well as offspring. In W. E. Nance (Ed.), *Twin research 3: Twin biology and multiple pregnancy* (pp. 107-114). New York: Alan R. Liss.

Crisp, A. H., Hall, A., & Holland, A. J. (1985). Nature and nurture in anorexia nervosa: A study of 34 pairs of twins, one pair of triplets, and an adoptive family. *International Journal of Eating Disorders, 4,* 5-27.

Dallapicolla, B., Stomeo, C., Ferranti, G., DiLecce, A., & Purpura, M. (1985). Discordant sex in one of three monozygotic triplets. *Journal of Medical Genetics, 22,* 6-11.

Day, E. (1932). The development of language in twins. A comparison of twins and single children. *Child Development, 3,* 179-199.

Dumont-Driscoll, M., & Rose, R. J. (1983). Testing the twin model: Is perceived similarity due to genetic identity? *Behavior Genetics, 13,* 531-532.

Eaves, L. J., & Eysenck, H. J. (1974). Genetics and the development of social attitudes. *Nature, 249,* 288-289.

Elwood, J. M. (1985). Temporal trends in twinning. In H. Kalter (Ed.), *Issues and reviews in teratology, 3* (pp. 65-93). New York: Plenum.

Engel, G. L. (1975). The death of a twin: Mourning and anniversary reactions. Fragments of 10 years of self-analysis. *International Journal of Psychoanalysis, 56,* 23-40.

Farber, S. L. (1981). *Identical twins reared apart: A reanalysis.* New York: Basic Books.

Farmer, A. E., McGuffin, P., & Gottesman, I. I. (1987). Twin concordance for DSM-III schizophrenia. *Archives of General Psychiatry, 44,* 634-641.

Freedman, D. G., & Keller, B. (1963). Inheritance of behavior in infants. *Science, 140,* 196-198.

Fuller, J., & Hahn, M. E. (1976). Issues in the genetics of social behavior. *Behavior Genetics, 6,* 391-406.

Fuller, J. L., & Thompson, W. R. (1978). *Foundations of behavior genetics.* St. Louis: Mosby.

Galton, F. (1875). The history of twins as a criterion of the relative powers of nature and nurture. *Journal of the Anthropological Institute, 5,* 391-406.

Garza-Chapa, R., Escobar, M. S., Cerda, R., & Leal-Garza, C. H. (1984). Factors related to the frequency of twinning in the state of Nuevo Leon, Mexico during 1977 and 1978. *Human Biology, 56,* 277-290.

Gesell, A. L., & Thompson, H. (1929). Learning and growth in identical twins. *Genetic Psychology Monographs, 6,* 5-120.

Gesell, A. L., & Thompson, H. (1941). Twins T and C from infancy to adolescence: A biogenetic study of individual differences by the method of co-twin control. *Genetic Psychology Monographs, 24,* 3-121.

Goldsmith, H. H. (1983). Genetic influences on personality from infancy to adulthood. *Child Development, 54,* 331-355.

Gottesman, I. I., & Shields, J. (1982). Schizophrenia: *The epigenetic puzzle.* Cambridge, England: Cambridge University Press.

Hay, D. A., Prior, M., Collett, S., & O'Brian, P. J. (1987). Speech and language development in preschool twins. *Acta Geneticae Medicae et Gemellologiae, 36,* 213-223.

Hilgard, J. R. (1933). The effect of early and delayed practice on memory and motor performance studied by the method of co-twin control. *Genetic Psychology Monographs, 14,* 493-567.

Hoaken, P. C. S., & Schnurr, R. (1980). Genetic factors in obsessive-compulsive neurosis. *Canadian Journal of Psychiatry, 25,* 167-172.

Holland, A. J., Hall, A., Murray, R., Russell, G. F. M., & Crisp, A. H. (1984). Anorexia nervosa: A study of 34 twin pairs and one set of triplets. *British Journal of Psychiatry, 145,* 414-419.

Horn, J. M., Plomin, R., & Rosenman, R. (1976). Heritability of personality traits in adult male twins. *Behavior Genetics, 6,* 17-30.

Inouye, E. (1972). Genetic aspects of neurosis. *International Journal of Mental Health, 1,* 176-189.

James, W. H. (1983). Dizygotic twinning, marital stage and coital rates. *Annuls of Human Biology, 8,* 371-378.

Jenkins, R. L., & Ashby, H. B. (1983). Gilles de la Tourette's syndrome in identical twins. *Archives of Neurology, 40,* 249-251.

Joseph, E. D., & Tabor, J. H. (1961). The simultaneous analysis of a pair of identical twins and the twinning reaction. *Psychoanalytic Study of the Child, 16,* 275-299.

Kaprio, J., Koskenvuo, M., Langinvainio, H., Romanov, K., Sarna, S., & Rose, R. J. (1987). Genetic influences on use and abuse of alcohol: A study of 5638 adult Finnish twin brothers. *Alcoholism: Clinical and Experimental Research, 11,* 349-356.

Kendler, K.S. (1983). Overview: A current perspective on twin studies of schizophrenia. *American Journal of Psychiatry, 140,* 1413-1425.

Koch, H. (1966). *Twins and twin relations.* Chicago: University of Chicago Press.

Kringlen, E. (1985). Depression research: A review with special emphasis etiology. *Acta Psychiatrica Scandinavica, 71,* 117-130.

Langinvainio, H., Kaprio, J., Koskenvuo, M., & Lönnqvist, J. (1984). Finnish twins reared apart: III. Personality factors. *Acta Geneticae Medicae et Gemellologiae, 33,* 259-264.

Levy, J. (1981). Lateralization and its implications for variation in development. In E. Gollin (Ed.), *Developmental plasticity: Behavioral and biological aspects of variations in development* (pp. 175-228). New York: Academic Press.

Littlefield, C. H., & Rushton, J. P. (1986). When a child dies: The sociobiology of bereavement. *Journal of Personality and Social Psychology, 51,* 797-802.

Locke, E. A. (1976). The nature and causes of job satisfaction. In M. D. Durincetti (Ed.), *Handbook of industrial and organizational psychology* (pp. 1297-1349). Chicago: Rand McNally.

Loehlin, J., & Nichols, R. (1976). *Heredity, environment and personality: A study of 850 sets of twins.* Austin, Texas: University of Texas Press.

Lykken, D. T. (1978). The diagnosis of zygosity in twins. *Behavior Genetics, 8,* 437-473.

Lykken, D. T., McGue, M. K., & Tellegen, A. (1987). Recruitment bias in twin research: The rule of two-thirds reconsidered. *Behavior Genetics, 17,* 343-362.

Lytton, H. (1980). *Parent-child interaction: The socialization process observed in twin and singleton families.* New York: Plenum.

Lytton, H., Conway, D., & Sauvé, R. (1977). The impact of twinship on parent-child interaction. *Journal of Personality and Social Psychology, 35,* 97-107.

Lytton, H., Watts, D., & Dunn, B. E. (1988). Stability of genetic determination from age 2 to age 9: A longitudinal twin study. *Social Biology, 35,* 62-73.

MacGillivray, I., Campbell, D. M., & Thompson, B. (1988). *Twinning and twins.* Chichester, England: Wiley.

Martin, N. G., Eaves, L. J., Heath, A. C., Jardine, R., Feingold, L. M., & Eysenck, H. J. (1986). Transmission of social attitudes. *Proceedings of the National Academy of Sciences, 83,* 4364-4368.

Matheny, A. P., Jr. (1987). Developmental research of twin's temperament. *Acta Geneticae Medicae et Gemellologiae, 36,* 135-143.

Matheny, A. P., Wilson, R. S., & Dolan, A. B. (1976). Relations between twin's similarity in appearance and behavioral similarity: Testing an assumption. *Behavior Genetics, 6,* 343-351.

McDiarmid, J. M., & Silva, P. A. (1979). Three-year-old twins and singletons: A comparison of some perinatal, environmental, experiential. and developmental characteristics. *Australian Paediatric Journal, 15,* 243-247.

McGraw, M. (1935). *Growth: A study of Johnny and Jimmy.* New York: Appleton-Century-Crofts.

McGuffin, P., & Mawson, D. (1980). Obsessive-compulsive neurosis: Two identical twin pairs. *British Journal of Psychiatry, 137,* 285-287.

Mittler, P. (1971). *The study of twins.* Harmondsworth, Middlesex, England: Penguin Books Ltd.

Mowrer, E. (1954). Some factors in the affectional adjustment of twins. *American Sociological Review, 19,* 468-471.

Newman, H. H., Freeman, F. N., & Holzinger, K. J. (1937). *Twins: A study of heredity and environment.* Chicago: University of Chicago Press.

Nichols, R. C. (1978). Twin studies of ability, personality and interests. *Homo, 29,* 158-173.

Nylander, P. P. S. (1975). Factors which influence twinning rates. In I. MacGillivray, P. P. S. Nylander, & G. Corney (Eds.), *Human multiple reproduction* (pp. 98-106). London: W. B. Saunders.

Osterweis, M., Solomon, F., & Green, M. (Eds.). (1984). *Bereavement: Reactions, consequences, and care.* Washington, DC: National Academy Press.

Pakstis, A., Scarr-Salapatek, S., Elston, R. C., & Siervogel, R. (1972). Genetic contributions to morphological and behavioral similarities among sibs and dizygotic twins: Linkages and allelic differences. *Social Biology, 19,* 185-792.

Paluszny, M., Selzer, M. L., Vinokur, A., & Lewandowski, L. (1977). Twin relationships and depression. *American Journal of Psychiatry, 134,* 988-990.

Parisi, P., Gatti, M., Prinzi, G., & Caperna, G. (1983). Familial incidence of twinning. *Nature, 304,* 626-628.

Parker, N. (1964). Twins: A psychiatric study of a neurotic group. *The Medical Journal of Australia, 2,* 735-742.

Pedersen, N. L., Plomin, R., McClearn, G. E., & Friberg, L. (1988). Neuroticism, extraversion and related traits in adult twins reared apart and together. *Journal of Personality and Social Psychology, 55,* 950-957.

Plomin, R. (1986). *Development, genetics and psychology.* Hillsdale, NJ: Erlbaum.

Plomin, R. (1989). Environment and genes: Determinants of behavior. *American Psychologist, 44,* 105-111.

Plomin, R., & Daniels, D. (1987). Why are children in the same family so different from one another? *Behavioral and Brain Sciences, 10,* 1-16.

Plomin, R., DeFries, J. C., & McClearn, G. E. (1990). *Behavioral genetics: A primer* (2nd ed.). San Francisco: Freeman.

Plomin, R., & Dunn, J. (1986). *The study of temperament: Changes, continuities and challenges.* Hillsdale, NJ: Erlbaum.

Plomin, R., & Loehlin, J. C. (1989). Direct and indirect IQ heritability estimates: A puzzle. *Behavior Genetics, 19,* 331-342.

Plomin, R., Pedersen, N. L., McClearn, G. E., Nesselrode, J. R., & Bergeman, C. S. (1988). EAS temperaments during the last half of the life span: Twins reared apart and twins reared together. *Psychology and Aging, 3,* 43-50.

Plomin, R., Willerman, L., & Loehlin, J. C. (1976). Resemblance in appearance and the equal environment assumption in twin studies of personality. *Behavior Genetics, 34,* 43-53.

Price, B. (1950). Primary biases in twin studies: A review of prenatal and natal difference-producing factors in monozygotic pairs. *American journal of Human Genetics, 2,* 293-352.

Price, R. A., Kidd, K. K., Cohen, D. J., Pauls, D. L., & Leckman, J. F.

(1985). A twin study of Tourette Syndrome. *Archives of General Psychiatry, 42,* 815-820.
Razel, M. (1985). A reanalysis of evidence for the genetic nature of early motor development. In I. E. Siegel (Ed.), *Advances in applied developmental psychology, 1* (pp. 171-211). Norwood, NJ: Ablex.
Rose, R. I., & Kaprio, J. (1988). Frequency of social contact and intrapair resemblance of adult monozygotic cotwins—or does shared experience influence personality after all? *Behavior Genetics, 18,* 309-328.
Rose, R. J., Reed, T., & Bogle, A. (1987). Asymmetry of a-b ridge count and behavioral discordance of monozygotic twins. *Behavior Genetics, 17,* 125-140.
Rothbart, M. K., & Derryberry, D. (1981). Development of individual differences in temperament. In M. E. Lamb & A. L. Brown (Eds.). *Advances in developmental psychology, 1* (pp. 37-86). Hillsdale, NJ: Erlbaum.
Rowe, D. C. (1986). Genetic and environmental components of antisocial behavior: A study of 265 twin pairs. *Criminology, 24,* 513-532.
Rowe, D. C., & Rodgers, J. L. (1989). Behavioral genetics, adolescent deviance, and "d": Contributions and issues. In G. R. Adams, R. Montemayor, & T. P. Gullotta (Eds.), *Biology of adolescent behavior and development* (pp. 38-67). Newbury Park, CA: Sage.
Sanders, C. M. (1979-1980). A comparison of adult bereavement in the death of a spouse, child, and parent. *Omega, 20,* 303-322.
Sanders, C. M. (1989). *Grief: The mourning after.* New York: Wiley.
Sanders, C. M., Mauger, P. A., & Strong, P. N. (1977). *A manual for the Grief Experience Inventory.* Palo Alto: Consulting Psychologists Press.
Savić, S. (1980). *How twins learn to talk.* London: Academic Press.
Scarr, S. (1969). Environmental bias in twins studies. In M. Manosevitz, G. Lindzey, & D. D. Thiessen (Eds.), *Behavioral genetics: Theory and method* (pp. 597-605). New York: Appleton-Century-Crofts.
Scarr, S., & Weinberg, R. A. (1978, April). Attitudes, interests and IQ. *Human Nature,* 29-36.
Scarr-Salapatek, S. (1975). Populations for the study of behavior traits. Commentary I. In K. W. Schaie, V. E. Anderson, G. E. McClearn, & J. Money (Eds.), *Developmental human behavior genetics* (pp. 77-83). Lexington, MA: Heath.
Scott, J. P. (1983). Genetics of social behavior in nonhuman animals. In J. Fuller & E. C. Simmel (Eds.), *Behavior genetics: Principles and applications* (pp. 363-371). Hillsdale, NJ: Erlbaum.
Segal, N. L. (1984a). Zygosity testing: Laboratory and the investigator's judgment. *Acta Genetica Medicae et Gemellologiae, 33,* 515-521.
Segal, N. L. (1984b). Cooperation, competition, and altruism within twin sets: A reappraisal. *Ethology and Sociobiology, 5,* 163-177.
Segal, N. L. (1985). Monozygotic and dizygotic twins: A comparative analysis of menial ability profiles. *Child Development, 56,* 1051-1058.
Segal, N. L., Dysken, M. W., Bouchard, T. J., Jr., Pedersen, N. L., Eckert, E. D., & Heston, L. L. (1990). Tourett's disorder in a set of reared-apart triplets: Genetic and environmental influences. *American Journal of Psychiatry, 147,* 196-199.
Shields, J. (1962). *Monozygotic twins: Brought up together and apart.* London: Oxford University Press.
Siemon, M. (1980). The separation-individuation process in adult twins. *American Journal of Psychotherapy, 34,* 387-400.
Smith, J. A., Renshaw D. C., & Renshaw, R. H. (1968). Twins who want to be identified as twins. *Diseases of the Nervous System, 29,* 615-618.
Springer, P., & Deutsch, G. (1985). *Left brain, right brain.* New York: Freeman.
Stevenson, J., & Fielding, J. (1985). Ratings of temperament in families of young twins. *British Journal of Developmental Psychology, 3,* 143-152.
Stevenson, J., Graham, P., Fredman, G., & McLoughlin, V. (1987). A twin study of genetic influences on reading and spelling ability and disability. *Journal of Child Psychology and Psychiatry, 28,* 229-247.
Suematsu, H., Kuboki, T., & Ogata, E. (1986). Anorexia nervosa in monozygotic twins. *Psychotherapy and Psychosomatics, 45,* 46-50.
Tambs, K., Sundet, J. M., Magnus, P., & Berg, K. (1989). No recruitment bias for questionnaire data related to IQ in classical twin studies. *Personality and Individual Differences, 10,* 269-271.
Taylor, H. F. (1980). *The IQ game: A methodological inquiry into the heredity-environment controversy.* New Brunswick, NJ: Rutgers University Press.
Tellegen, A., Lykken, D. T., Bouchard, T. J., Jr., Wilcox, K. J., Segal, N. L., & Rich, S. (1988). Personality similarity in twins reared apart and together. *Journal of Personality and Social Psychology, 54,* 1031-1039.
Thomas, A., Chess, S., & Birch, H. G. (1968). *Temperament and behavior disorders.* New York: New York University Press.
Torgersen, A. M. (1981). Genetic factors in temperamental individuality. *Journal of the American Academy of Child Psychiatry, 20,* 702-711.
Torgersen, A. M. (1987). Longitudinal research on temperament in twins. *Acta Geneticae Medicae et Gemellologiae, 36,* 145-154.
Torgersen, A. M., & Kringlen, E. (1978). Genetic aspects of temperamental differences in infants. *Journal of the American Academy of Child Psychiatry, 17,* 433-444.
Vandenberg, S. G. (1966). Contributions of twin research to psychology. In M. Manosevitz, G. Lindzey, & D. D. Thiessen (Eds.), *Behavioral genetics: Method and research* (pp. 145-164). New York: Appleton-Century-Crofts.
Vandenberg, S. G., & Wilson, R. S. (1979). Failure of the twin situation to influence twin differences in cognition. *Behavior Genetics, 9,* 55-60.
Vieregge, P., Schäfer, C., & Jörg, J. (1988). Concordant Gilles de la Tourette's syndrome in monozygotic twins: A clinical, neurophysiological and CT study. *Journal of Neurology, 235,* 366-367.
Vogel, F., & Motulsky, A. G. (1979). *Human genetics.* New York: Springer-Verlag.
Von Bracken, H. (1934). Mutual intimacy in twins. *Character and Personality, 2,* 293-309.
Waserman, J., Lal, S., & Gauthier, S. (1983). Gilles de la Tourette's syndrome in monozygotic twins. *Journal of Neurology, Neurosurgery, and Psychiatry, 46,* 75-77.
Weinberg, R. A. (1989). Intelligence and IQ: Landmark issues and great debates. *American Psychologist, 44,* 98-104.
Wilde, G. J. S. (1974). Inheritance of personality traits. *Acta Psychologia, 22,* 37-51.
Willerman, L. (1973). Activity level and hyperactivity in twins. *Child Development, 44,* 288-293.
Wilson, R. S. (1979). Twin growth: Initial deficit, recovery, and trends in concordance from birth to nine years. *Annals of Human Biology, 6,* 205-220.
Wilson, R. S. (1983). The Louisville Twin Study: Developmental synchronies in behavior. *Child Development, 54,* 298-316.
Wilson, R. S., & Matheny, A. (1986). Behavior-genetics research in infant temperament: The Louisville Twin Study. In R. Plomin & J. Dunn (Eds.), *The study of temperament: Changes, continuities and challenges* (pp. 81-97). Hillsdale, NJ: Erlbaum.
Woodward, J. (1987). The bereaved twin. *Acta Geneticae Medicae et Gemellologiae, 37,* 173-180.
Wyshak, G., Honeyman, M. S., Flannery, J. T., & Beck, A. S. (1983). Cancer in mothers of dizygotic twins. *Journal of the National Cancer Institute, 70,* 593-599.
Zazzo, R. (1978). Genesis and peculiarities of the personality of twins. In W. E. Nance, G. Allen, & P. Parisi (Eds.), *Twin research (Part A): Psychology and method* (pp. 1-11). New York: Alan R. Liss.

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