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REPRINTS AND REFLECTIONS

Why are children in the same family so different from one another?*

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Summary One of the most important findings that has emerged from human behavioral genetics involves the environment rather than heredity, providing the best available evidence for the importance of environmental influences on personality, psychopathology, and cognition. The research also converges on the remarkable conclusion that these environmental influences make two children in the same family as different from one another as are pairs of children selected randomly from the population.

The theme of the target article is that environmental differences between children in the same family (called ''nonshared environment'') represent the major source of environmental variance for personality, psychopathology, and cognitive abilities. One example of the evidence that supports this conclusion involves correlations for pairs of adopted children reared in the same family from early in life. Because these children share family environment but not heredity, their correlation directly estimates the importance of shared family environment. For most psychological characteristics, correlations for adoptive ''siblings'' hover near zero, which implies that the relevant environmental influences are not shared by children in the same family. Although it has been thought that cognitive abilities represent an exception to this rule, recent data suggest that environmental variance that affects IQ is also of the nonshared variety *after adolescence.*

The article has three goals: (1) To describe quantitative genetic methods and research that lead to the conclusion that nonshared environment is responsible for most environmental variation relevant to psychological development, (2) to discuss specific nonshared environmental influences that have been studied to date, and (3) to consider relationships between nonshared environmental influences and behavioral differences between children in the same family. The reason for presenting this article in *BBS* is to draw attention to the far-reaching implications of finding that psychologically relevant environmental influences make children in a family different from, not similar to, one another.

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The findings of greatest social significance to emerge from human behavioral-genetic research to date involve nurture, not nature. Research in this area, consisting primarily of twin and adoption studies, points to significant genetic influence on individual differences for a wide range of behaviors, including personality, psychopathology, and cognition. When we go beyond the statistical significance of genetic influence to ask about the effect size, it is also apparent that genetic influence is substantial. Nonetheless, the same data provide evidence - indeed, we think the best available evidence - for the importance of environmental variation in each of these domains.

Ten years ago, in order to redress the imbalance of environmentalism, it was necessary to emphasize the possibility that genetic influence could affect behavioral differences that we observe among individuals. Now behavioral geneticists find that they must more often emphasize the importance of environmental variation. Behavioral-genetic research seldom finds evidence that more than half of the variance for complex behavioral traits is due to genetic differences among individuals.

Thus, for personality, psychopathology, and cognition, behavioral-genetic research converges on the conclusion that most behavioral variability among individuals is environmental in origin. For example, for schizophrenia, the concordance for first-degree relatives, whose coefficient of genetic relationship is .50, is less than 10%. Identical twins are less than 50% concordant for schizophrenia. Yet schizophrenia is coming to be viewed as a genetic disease. In the rush to find neural causes of schizophrenia, who is now studying the major source of variability - the environment?

Not only does behavioral genetic research document the importance of environmental influence, it also points to a possible treasure of environmental variance hidden in unexplored territory. This research implies that environmental influences that affect psychological development operate in a manner quite different from the way most psychologists thought they worked. Whatever they may be, these environmental influences make children in the same family as different from one another as are children in different families. One purpose of this article is to describe the evidence that leads to this conclusion and its implications. Our main goal, however, is to draw attention to this dramatic discovery and to elicit commentary and suggestions from our peers. Despite the far-reaching implications of the evidence that psychologically relevant environmental influences make children in a family different from rather than similar to each other, we are aware of no major criticism of these findings. We expect that *BBS* commentary will rock this boat's smooth sailing and perhaps even alter its course.

1. Quantitative genetics

In order to understand the evidence pointing to the importance of nonshared environment it is necessary to begin with an overview of the theory and methods of quantitative genetics, which, when applied to behavioral phenomena, is referred to as behavioral genetics. After describing the basic twin and adoption designs, we shall examine the implications of twin and adoption data for the separation of shared and nonshared environmental variation in the three domains with the most relevant data: personality, psychopathology, and cognition.

Quantitative genetic theory began in the early part of this century as a solution to the problem of reconciling Mendelian genetics with normal distributions. As anyone who has taken high school biology knows, about a hundred years ago, the monk Gregor Mendel studied dichotomous, either/or, characteristics such as round versus wrinkled seeds in the pea plant. When his work was rediscovered 30 years later it provoked controversy among biometricians who felt that the laws of heredity described by Mendel could not apply to human characteristics because, unlike discontinuous pea plant characteristics, human characteristics nearly always involve a normal, continuous distribution. The resolution to the controversy came when it was understood that a normal distribution would be observed if several genes affected a characteristic. In 1918, when Ronald Fisher put the finishing touches on this theory and spelled out the expectations for familial resemblance based on the theory, quantitative genetics was born.

The theory uses the covariance or correlation among relatives on normally distributed traits to estimate the role of heredity. Although the theory and its methods are usually presented in a sophisticated algebraic manner, the basic idea - which is all that is needed to understand the way in which environmental variation is partitioned in quantitative genetics - is very simple. Details, such as the distinction between additive and nonadditive genetic variance, can be found in textbooks on the topic [1,2,3]. The fundamental tenet of the theory is that individuals in a population differ for both genetic and nongenetic reasons. How can we assess the extent to which phenotypic (observed) variability is due to genetic variation among individuals or to nongenetic differences? In studies of human beings, for whom selection studies or comparisons among inbred strains cannot be conducted, the only way is to study pairs of individuals who differ in genetic resemblance. If heredity is important for a particular characteristic, pairs of individuals who are more similar genetically ought to be more similar for the measured characteristic. For example, third-degree relatives such as cousins will be less similar than second-degree relatives such as half-siblings who, in turn, will be less similar than first-degree relatives such as full siblings. If heredity does not affect the trait, then differences in genetic similarity should not affect the resemblance of these pairs of individuals.

The problem is that environmental resemblance often covaries with genetic relatedness: Cousins, half-siblings, and full siblings, respectively, are likely to share increasingly similar environments. Because relatives share family environment as well as heredity, familial resemblance can be due to environmental influences as well as to hereditary influences. In other words, a portion of environmental influence could be shared by relatives, making them similar to one another. Nonetheless, family studies are useful in estimating limits of genetic and environmental influences. For example, if the correlation for first-degree relatives is zero for a particular trait, then neither shared heredity nor shared family environment affect the trait.

The two major designs of human behavioral genetics - the adoption design and the twin design - were developed to circumvent the problem of conflating genetic and environmental influences in studies of family members who share heredity and family environments. By doing so, these designs partition environmental variance into two components: one shared by members of a family and the other consisting of the remainder of the environmental variance, which is referred to as nonshared environment.

1.1 Adoption design

The basic problem in family studies is that resemblance among relatives could be due to shared heredity or to shared environment. The adoption design powerfully cleaves these two sources of familial resemblance. Genetically related individuals adopted apart and reared in uncorrelated environments will resemble each other only for genetic reasons. Genetically unrelated individuals adopted together in the same family will resemble each other only for reasons of shared environment.

The simplest adoption design to understand is the rare, but dramatic, situation in which identical twins are adopted separately at birth and reared apart in uncorrelated environments. The resemblance of these pairs of twins, expressed as a correlation, is a direct estimate of the proportion of phenotypic variance that is due to genetic variance, a descriptive statistic known as heritability. A correlation of .50 for identical twins reared apart implies that half of the phenotypic variance is genetic in origin. The correlation is not squared because the issue is not whether we can predict one twin's score from the other twin's score. Rather, the issue is the extent to which observed variance is due to shared variance - that is covariance - among the pairs. The correlation itself rather than its square expresses the proportion of total variance that is shared within pairs.[4,5]

A technical point that has some bearing on the estimation of nonshared environment concerns the distinction between additive and nonadditive genetic variance. Identical twins share all sources of genetic variance, no matter how complex the interactions among genes. Thus, an estimate of heritability derived from the correlation for identical twins reared apart is referred to as broad heritability - it includes all sources of genetic variance. In contrast, first-degree relatives primarily share only additive genetic variance, genetic effects that add up linearly in their effect on the phenotype; estimates of heritability based on first-degree relatives adopted apart are thus primarily limited to additive genetic variance and are thus referred to as narrow heritability. This distinction is important to the extent that nonadditive genetic variance is important; if nonadditive genetic variance affects a trait, behavioral genetic designs that assess narrow heritability will misread this genetic variance as nonshared environment. Although most behavioral geneticists discount the importance of nonadditive genetic variance, some recent work suggests that it contributes to certain characteristics[6,7].

Phenotypic variance not explained by genetic variance is ascribed to environmental sources. More properly, this component of variance is nongenetic; that is, it is broader than the usual way psychologists think about the environment in that it includes accidents and illnesses, prenatal influences, cytoplasmic changes, and even DNA changes that are not transmitted hereditarily. Data for relatives adopted apart, as in the case of separately adopted identical twins, cannot by themselves separate shared and nonshared environmental components of nongenetic variance.

Other adoptions designs can assess shared and nonshared environment. Comparisons between relatives adopted apart and relatives reared together permit an indirect assessment. Relatives adopted apart share heredity but not environment, whereas relatives reared together are similar for reasons both of shared heredity and shared environment. If relatives reared together are no more similar than relatives adopted apart we can conclude that growing up in the same family does not add to relatives' resemblance beyond the similarity induced by heredity. In other words, environmental influence operates in a nonshared manner. For example, if, for a particular trait, identical twins reared together are no more similar than identical twins reared in uncorrelated environments, shared environment is unimportant for that trait and all of the environmental variance must be nonshared. On the other hand, if the correlation for identical twins reared together is .75 and the correlation for identical twins reared apart is .50, 25% of the phenotypic variance could be attributed to shared environment and the remaining 25% to nonshared environment.

We have included this concrete example of partitioning only for purposes of clarification. We do not mean to convey that such estimates will be particularly precise. The accuracy of the estimates depends on all of the usual statistical issues such as sample size as well as on the assumptions of behavioral genetic designs. The estimates of nonshared environment described later in our review come from large samples, are replicated in many studies, and are based on quite different designs such as adoption as well as twin studies. Moreover, our estimate of nonshared environment would have to be very substantially wrong before it would seriously affect our conclusion that nonshared environment is responsible for most environmental variation relevant to psychological phenomena.

A direct test of the importance of shared environment comes from the other side of the adoption design in which genetically unrelated individuals are adopted into the same family. These adoptive family members share major features of their environment - the same parents, home, social class, community, schools, and so forth - but they do not share heredity. The correlation for pairs of unrelated children adopted together directly estimates the proportion of phenotypic variance due to shared environment. For example, a correlation of .25 for a trait measured in pairs of adoptees reared in the same adoptive homes suggests that 25% of the phenotypic variation in the trait can be explained by shared environment. A correlation of zero for pairs of adoptees, on the other hand, implies that shared environment contributes nothing to phenotypic variance, which implies that all of the environmental variation is nonshared.

It should be mentioned that the distinction between shared and nonshared environment is not limited to family relationships in which relatives are the same age (such as twins), or relatives who are nearly the same age (such as siblings). We can also consider shared and nonshared environmental factors that affect the resemblance between parents and their offspring. In this case, shared environment refers to environmental influences that increase resemblance between parents and offspring. It does not involve all parental influences on offspring, only those environmental influences that increase phenotypic similarity between parents and their children.

1.2. Twin design

The twin design compares the resemblance of identical twins with that of same-sex fraternal twins. Both types of twins are born at the same time, share the same womb and home, and are of the same sex. One major difference distinguishes the two types: Identical twins are twice as similar genetically (on the average) as fraternal twins. If heredity affects a trait, the twofold greater genetic similarity of identical twins will make them more similar than fraternal twins with respect to a particular trait. The difference between the correlations for identical twins and fraternal twins is an estimate of roughly half of the genetic variance in the population because the coefficient of genetic relationship is 1.0 for identical twins and .50 for fraternal twins. Thus, for a trait completely determined by heredity, the expected correlations are 1.0 for identical twins and .50 for fraternal twins. If the pattern of twin correlations were .75 and .50 for identical and fraternal twins, respectively, heredity would be estimated to explain half of the phenotypic variance for the trait. If heredity does not affect the trait, the twofold greater genetic similarity of identical twins will not make them more similar than fraternal twins for the particular trait.

This discussion has oversimplified the twin method for didactic purposes. For example, assortative mating would raise the fraternal twin correlation and nonadditive genetic variance would lower it. Also, even though twin partners of both types live in the same family, it is possible that identical twins experience more similar family environments than do fraternal twins. If this were the case, some of the greater observed similarity of identical twins might be due to greater similarity of their experience. This possible confounding effect has been examined and, in research to date, does not appear to represent a major problem for the twin design[3]. Finally, genotype-environment interaction and correlation can affect these estimates, as discussed later.

If genetic variance accounts for 50%, of the phenotypic variance, the rest of the phenotypic variance is attributed to nongenetic variance, which includes shared and nonshared environment as well as error of measurement. The twin method can be used to partition nongenetic variance into its shared and nonshared components. Consider two patterns of identical vs. fraternal twin correlations: .75 vs. .50 and .50 vs. .25. Doubling the difference between the twin correlations suggests a heritability of 50% for both patterns of correlations. Thus, for both patterns, the proportion of phenotypic variance due to environmental variance is 50%. In the first case, however, the one with correlations of .75 and .50 for identical and fraternal twins, respectively, half of the environmental variance is shared by the twins, making them resemble each other, and the other half of the environmental variance makes them different. In the case of identical and fraternal twin correlations of .50 and .25, all of the environmental variance contributes to differences within pairs.

The reasoning behind this conclusion is as follows: Differences within pairs of identical twins are due only to nongenetic factors not shared by twins because members of identical twin pairs do not differ genetically. Thus, when identical and fraternal twin correlations are .50 and .25, respectively, .50 of the phenotypic variance is genetic and .50 is nongenetic. Because identical twins are identical genetically and yet their phenotypic correlation is only .50, all of the nongenetic variance (specifically, nonshared environment and error of measurement) leads to differences within pairs. Variance due to error of measurement can be assessed as the difference between the reliability coefficient (e.g. test-retest correlation) and 1.0. For example, if a test-retest correlation is .90, error variance is 10%; the 50% nongenetic variance thus consists of 40% nonshared environmental variance and 10% error variance. When the identical and fraternal twin correlations are .75 and .50, half of the phenotypic variance is again environmental, but in this case only half of the environmental variance (25% of the total phenotypic variance: $1.0 - .75 = .25$) is due to nonshared environment and error and the other half is shared. The shared environment component of variance can be estimated as twice the fraternal twin correlation minus the identical twin correlation.

In summary, the twin design provides a direct estimate of nonshared environment - the component of phenotypic variance that is not shared by members of identical twin pairs. In addition, the twin design provides an indirect estimate of shared family environment: It is the component of phenotypic variance that remains after accounting for genetic variance and nonshared environmental variance. The generalizability of twin results concerning shared family environment to the population of nontwin siblings is questionable, however, because it seems likely that twins share family environments to a greater extent than do siblings who are not twins, as will be discussed later.

Thus, adoption and twin studies can separate environmental variance for behavioral traits into two components. One component, called shared environment, includes all environmental influences that make children in a family similar to one another. This component of variance can be estimated in three ways: (1) from the correlation for genetically unrelated children reared together in the same adoptive families, (2) from the difference in correlations for relatives reared together and relatives adopted apart, and (3) from twin studies, as the remainder of phenotypic variance when genetic variance, variance due to nonshared environment, and error are removed. Environmental variance not due to shared environment is called nonshared environment; this portion of environmental variance makes family members different from one another. This variance component is usually estimated as the remainder of phenotypic variance once variance due to heredity, shared environment, and error of measurement is removed. Differences within pairs of identical twins reared together provides a direct estimate of nonshared environment as experienced by identical twins.

Because we are developmentalists, we feel compelled to make the point that all components of variance can change during development. Estimates of genetic and environmental components of variance depend upon the age of the subjects sampled. Genetic change during development is the focus of a new subdiscipline, developmental behavioral genetics[7]. Nonshared and shared environmental components can also change during development. Research is needed to trace the developmental course of shared and nonshared environmental variance. For example, there may be a general trend for nonshared environmental variance to increase with age as individuals expand their social and environmental networks beyond the family. On the other hand, as this happens, there may be fewer forces contrasting children in the same family. Research throughout the lifespan - especially research past adolescence - will be needed to resolve such developmental issues. One striking example of developmental change in the relative influence of shared and nonshared environmental variance serves to indicate the potential usefulness of a lifespan perspective: For IQ, the shared environment component of variance diminishes dramatically after childhood, as discussed in the next section.

2. Evidence for the importance of nonshared environmental effects on behavior

This section provides a brief summary of behavioral-genetic research in personality, psychopathology, and cognition that leads to the conclusion that the most important source of environmental variance is nonshared environment. This material is based on a recent review of behavioral-genetic research throughout the lifespan which can be consulted for additional studies and details[7]. Although readers might take issue with the precise magnitude of one or another of the estimates, the forest should not be overlooked for the trees. Our point, one that to our knowledge has not been disputed, is that nonshared environment is responsible for most environmental variation relevant to psychological development. Thus, our goal in the following section is not to provide an encyclopedic review of behavioral-genetic studies but rather to summarize the results to the extent needed to understand their message regarding the importance of nonshared environment.

2.1. Personality

The importance of nonshared environment was first highlighted by Loehlin and Nichols[8] whose twin analyses of personality data led to the following conclusion:

> Thus, a consistent - though perplexing - pattern is emerging from the data (and it is not purely idiosyncratic to our study). Environment carries substantial weight in determining personality - it appears to account for at least half the variance - but that environment is one for which twin pairs are correlated close to zero . . . In short, in the personality domain we seem to see environmental effects that operate almost randomly with respect to the sorts of variables that psychologists (and other people) have traditionally deemed important in personality development[8]. [p. 92]

Loehlin and Nichols reached this conclusion because identical and fraternal twin correlations were consistently about .50 and .30, respectively, within their large study of high-school-aged twins that used self-report personality questionnaires. This pattern of correlations suggests 40% genetic variance and 60% environmental variance, and that over 80% of the environmental component of variance is due to nonshared environment plus error. (Error accounts for about 20% of the variance.)

These results are not peculiar to Loehlin and Nichols's study of high-school twins. In a review of 10 recent twin studies of personality[9], the average twin correlations were .47 for identical twins and .23 for fraternal twins. This pattern of twin correlations suggests that heredity accounts for 50% of the phenotypic variance and that nonshared environment and error of measurement explain the rest.

It might seem odd to report average correlations across a domain as diverse as personality. Nonetheless, the twin results are generally similar across the dozens of traits measured by self-report questionnaires. Consider extraversion and neuroticism, the two ''super-factors'' in personality, which are associated with Eysenck[10] but also emerge as major second-order factors from other personality questionnaires such as Cattell's Sixteen Personality Factor Questionnaire[11]. [See also Zuckerman: ''Sensation Seeking'' *BBS* 7(3) 1986]. A study of over 12,000 adult twin pairs in Sweden[12] revealed twin correlations of .51 and .21 for identical and fraternal twins, respectively, for extraversion and correlations of .50 and .23 for neuroticism.

Similar results emerge for less central dimensions of personality as well. For example, Loehlin and Nichols's study used the California Psychological Inventory, which includes diverse scales such as Sense of Well-Being, Tolerance, and Good Impression. The identical and fraternal twin correlations, respectively, for these scales were .50 and .30, .53 and .35, and .48 and .30. Another example involves twin results for a new personality questionnaire, the Differential Personality Questionnaire, which assesses nontraditional dimensions of personality. A twin study of over 200 identical twin pairs and over 100 fraternal twin pairs yielded the following sampling of correlations for identical and fraternal twins, respectively: .50 and .36 for Danger Seeking; .61 and .37 for Authoritarianism; and .58 and .25 for Alienation[13]. The only personality trait that appears to show significant shared environmental influence is masculinity-feminity, which one might argue falls more in the category of attitudes than personality[14].

These twin studies used self-report questionnaires. Perhaps some artifact exists so that identical twins always rate themselves as 50% similar when asked about their personality. Other assessment procedures, however, yield similar results. For example, in recent years, several twin studies using parental ratings of children's personality have been reported[15]. The average identical twin correlation is about .50, again suggesting that about half of the variance is due to nonshared environment. The few twin studies that have used objective observations of personality yield somewhat less ubiquitous evidence for nonshared environmental variance than do paper-and-pencil questionnaire[16]. Nonetheless, estimates of nonshared environmental influence from these studies are still substantial - usually greater than estimates of shared environmental variance, even when error variance is taken into account.

Studies of nontwin siblings and other family relationships confirm the hypothesis that shared family environment accounts for a negligible amount of environmental variance relevant to personality development. For example, one of the earliest studies found an average sibling correlation of .12 [17]; a recent large family study[18] yielded an average sibling correlation of .16 for three widely used personality questionnaires. The average parent/offspring correlations in this study were also low: .12 for father/son, .10 for father/daughter, .13 for mother/son, and .14 for mother/daughter.

Four recently reported adoption studies of personality indicate that this modest familial resemblance is not due to shared family environment - the average adoptive sibling correlation is .04 and the average adoptive parent/adopted child correlation is .05[19,20,21,22]. Adoptive sibling correlations are also low in the first report of infant adoptive siblings, involving 61 pairs at 12 months and 50 pairs at 24 months tested as part of the Colorado Adoption Project[23]. Parental ratings of temperament yielded average adoptive sibling correlations of .11 at 12 months and .05 at 24 months; tester ratings on the Infant Behavior Record[24] yielded average adoptive sibling correlations of −.14 at 12 months and .05 at 24 months.

2.2. Psychopathology

Behavioral-genetic data on psychopathology are also consistent with the conclusion that environmental variation is preponderantly of the nonshared variety. Research on schizophrenia is difficult to summarize briefly because concordance rates vary widely depending on the following: whether or not age correlations are used, the type of diagnostic criteria used, and the selection and severity of probands. Nonetheless, relying on a recent book-length review[25], familial concordance rates for schizophrenia in a dozen studies found about 10% concordance rates for schizophrenia for first-degree relatives. The concordance rate for fraternal twins is also about 10%. Concordance rates for identical twins are substantially higher than those for fraternal twins - indeed, higher than would be expected on the basis of a simple additive genetic model in which identical twins would be about twice as similar as fraternal twins. For example, Gottesman and Shields review five recent studies that yield an average case-wise concordance of 45% for identical twins. Regardless of the complications this pattern of twin concordance causes for estimates of genetic influence, the results indicate that most schizophrenic identical twins do not have an affected cotwin. Because these are genetically identical pairs of individuals, nonshared environment must be the reason for these striking differences within pairs of identical twins.

This conclusion is confirmed in Gottesman and Shields's review of recent adoption studies in Denmark in which the same concordance of about 10% is found for individuals adopted apart from a first-degree schizophrenic relative. Thus, sharing the same family environment with a schizophrenic relative does not increase familial concordance.

Gottesman and Shields[25] also review attempts to isolate environmental sources of variance and conclude:

> So far, *no* specific environmental source of liability is known; the most likely environmental contributor, stress, may come from many sources and, apparently, may come during any stage of development. Prenatal or birth complications, early deprivations, broken homes, censuring parents, the death of someone close, failures in school, poor work or social relationships, childbirth, a bad drug trip, as well as all kinds of *good* fortune may have effects on a predisposed individual that are obvious only in retrospect. In prospect, it will be impossible to prophesy the events themselves, let alone their effects[25] [241-42].

We suggest, however, that until more systematic research on nonshared environmental variance sources is conducted it is too early to conclude that the large environmental component of variance in schizophrenia is brought about by idiosyncratic experiences.

Research on manic-depressive psychosis yields results similar to those for schizophrenia[3]. Environmental influences on less severe forms of psychopathology, such as neuroses and alcoholism, also appear to be predominantly nonshared. Sibling concordances are generally less than 20% and when twin and adoption studies have been conducted most of this familial resemblance has been found to be genetic in origin[26,27]. In other words, the most important influences on psychopathology lie in the category of nonshared environment. Much more often than not, affected children in families with more than one child will have unaffected siblings.

2.3. Cognition

Until recently, environmental variance that affects individual differences in IQ was thought to fall primarily in the category of shared environment. In 11 studies, the average IQ correlation for adoptive siblings is .30, suggesting that 30% of the variance in IQ scores is due to shared environmental influences[28]. Adoptive parent/adopted child IQ correlations are lower, about .20, but still suggest substantial influence of shared environment on parent-offspring resemblance. Twin studies agree: The average IQ correlation in over 30 studies is .85 for identical twins and .58 for fraternal twins[28], which suggests again that about 30% of the variance of IQ scores can be accounted for by shared environment.

Although these data appear to converge on the reasonable conclusion that shared environment accounts for a substantial portion of environmental variance relevant to IQ, doubts have begun to arise. For fraternal twins, who share environment to a greater extent than do nontwin siblings, the IQ correlation is about .60, whereas the correlation for nontwin siblings is about .40 - which means that the twin method overestimates the importance of shared environmental in comparison to family studies.

The crucial piece of evidence in support of substantial shared environmental variance is the correlation of .30 for adoptive siblings reared together. These studies have included adoptive siblings still living at home, with two exceptions. The first exception is a study of postadolescent adoptee pairs by Scarr and Weinberg[22] which found a correlation of −.03 for IQ. This unsettling finding implies that shared environment is important for IQ during childhood when children are living at home and then fades in importance after adolescence when children have left home.

The hypothesis that shared environmental influences have no lasting impact on IQ is supported by results of a recent study of adoptive and nonadoptive siblings[29]. The study included 52 pairs of adoptive siblings and 54 pairs of nonadoptive siblings ranging from 9 to 15 years of age, with the average age of 13 years. A battery of cognitive ability measures was developed for administration over the telephone; this battery correlated with face-to-face testing near the reliabilities of the tests. An unrotated first principal component, used as an index of IQ, yielded a reasonable correlation of .38 for nonadoptive siblings; however, the IQ correlation for adoptive siblings was −.16, not significantly different from zero. A similar pattern of results emerged for specific cognitive abilities. The adoptive sibling correlations for verbal, spatial, perceptual speed, and memory abilities were −.06, −.07, −.10, and .16, respectively.

Thus, this study leads to the conclusion that shared environmental influence on IQ and specific cognitive abilities is of negligible importance by the end of early adolescence. Because these estimates of shared environmental influences were obtained directly from adoptive sibling correlations, reasonable confidence can be attached to this conclusion. For example, the sample of 52 pairs of adoptive siblings permits detection of a true correlation of .30 with 70% power; the standard error of the estimates of shared environment were found to be between .10 and .14 when a multiple regression model-fitting approach suggested by DeFries and Fulker[30] was used.

In summary, nonshared environmental influence is a major component of variance for personality, psychopathology, and IQ (after childhood). We conclude that nonshared environment explains perhaps as much as 40% to 60% of the total variance for these domains. Although one can quibble with the magnitude of our estimates, they would have to be substantially in error before they would affect our argument that most of the environmental variance is nonshared.

3. Shared and nonshared environmental variance

The purpose of this section is to consider some conceptual details of the distinction between shared and nonshared environment before discussing sources of nonshared environment. These details include other labels for shared and nonshared environment, the distinction between environmental components of behavioral variance and the relationship between specific environmental measures and behavior, the impact of nonshared environmental influence on the development of singletons, genotype-environment correlation and interaction, and model-fitting.

3.1. Other labels

Shared and nonshared environmental influences were named by Rowe and Plomin in 1981, although the distinction between environmental influences that contribute to the resemblance between relatives and those that do not has been implicit in quantitative genetics since its inception. Many labels have been used to refer to these two components of environmental variance. Shared environmental influence has been called E2, between-family, and common environmental variance, labels that have been used to refer to nonshared environmental include El, within-family, individual, unique and specific environmental variance. Rowe and Plomin suggested that the symbols El and E2[31] are probably best in that they carry no connotations, although they have the distinct disadvantage that they provide no mnemonic to remember which is which. Within- and between-family environment are the terms most often used. They are useful for those familiar with the terminology of analysis of variance which considers variance within and between groups. Variance within families refers to differences among family members and variance between families describes resemblance among family members. The term ''within-family'' environment, however, connotes factors that occur within the confines of the family; whereas nonshared influences are those that cause family members to differ regardless of whether the locus of influence is the family (such as differential treatment by parents) or outside the family (such as different experiences at school or with peers). For these reasons, we suggest that the most descriptive and straightforward terms to use are shared and nonshared.

3.2. Components of variance versus specific measures

It should be noted that this discussion pertains to environmental components of behavioral variance, not to the relationship between specific environmental measures and behavioral measures. In this sense, quantitative genetic analyses describe the ''bottom line'' of genetic and environmental influence. That is, the total impact of genetic variability on phenotypic variability will be detected regardless of the complexity of the genetic effects - for example, whether the genetic effects arise from variability in structural genes that code for polypeptides or from regulatory genes. Similarly, quantitative genetics estimates the bottom line of environmental influence, regardless of the specific mechanisms by which environmental factors affect behavior. Although this components of variance approach may be unsatisfying for those who would like to know which specific genes and which specific environmental factors are responsible for the components of variance, it seems to be a reasonable first step to ask about components of variance - without this tack, we would not have discovered that nearly all environmental variance is of the nonshared variety. It is a major strength of the approach that it can reveal the presence of genetic and environmental influences even when these are not assessed directly.

Attempts to isolate specific environmental factors will be presented later. A related issue, however, should be mentioned at this time. Traditional environmental research attempts to relate measures of family environment to measures of behavior of one child per family. The yield from such research has been disappointing, especially if one considers the amount of variance explained[32]. Knowing this research, one might ask why such environmental factors as parental affection should be important *within* families when they account for little variance in behavior *across* families. That is, if it makes little difference that some parents love their children more than other parents love their children, why should parental love make a difference within families if a parent loves one child more than another? The answer is that there is no necessary relationship between the causes of differences *between* families and the causes of differences *within* families. That is, environmental factors that create differences within families can act independently of factors that cause differences between families. For example, a child really knows only his own parents; the child does not know if his parents love him more or less than other parents love their children. A child is likely to be painfully aware, however, that parental affection toward him is less than toward his sibling.

3.3. Singletons

Because over 80% of U.S. families have more than one child, it is important to understand why children in a family are so different from one another. How does nonshared environment relate to singletons? In general, reasons why two children in the same family differ are likely to yield clues as to the environmental source of variance for singletons as well. The easiest example involves nonsystematic events such as accidents and illnesses which are just as likely to befall singletons. However, systematic nonshared influences may also be found to affect singleton variance. For example, if certain characteristics of peer groups differ within pairs of siblings and contribute importantly to behavioral differences within sibling pairs, it is likely that these characteristics also contribute to variance for singletons.

Obviously, singletons do not have siblings with whom they interact; thus, this potential source of nonshared environment cannot contribute variance for singletons. Although it might seem at first that differential parental treatment of two children in the same family is irrelevant to singletons, it is possible that, once identified, such factors might contribute to the variance of singletons. There is evidence that parents with more than one child treat the children similarly if we look at the children at the same age, which suggests that parental treatment is not an important source of nonshared environment[33]. Except for twins, however, siblings are not the same age, and when we examine contemporaneous parental treatment of children of different ages, we find that parents treat the children differently[34]. Differences in parental behavior during development can also affect singletons in that parents will treat their singleton children differently during the course of development.

Thus, studies of differences within pairs of siblings are likely to illuminate factors responsible for singleton variance as well as sibling variance. The important point in the present context is the obvious one: that the study of singletons cannot isolate factors that make two children in the same family different from one another. Because this is the best clue we have as to the source of environmental variance relevant to psychological development, it makes sense to focus on environmental sources of differences between children in the same family.

3.4. Genotype-environment correlation and interaction

Two complicating factors in the estimation of quantitative genetic parameters are genotype-environment correlation and genotype-environment interaction[35]. Genotype-environment correlation refers to an increase in phenotypic variance that occurs when children experience environments correlated with their genetic propensities. Phenotypic variance can also be due to genotype-environment interaction when children respond differently to the same environment because of genetic differences among them. What are the effects of genotype-environment correlation and interaction on estimates of shared and nonshared environment? Consider a direct estimate of nonshared family environment: the extent to which the correlation for identical twins reared together is less than 1.0. This estimate will not include either genotype-environment correlation or interaction because identical twins are identical genetically; thus, in terms of genetic propensities, identical twins will correlate and interact with the environment in a similar manner. Similarly, the direct estimate of shared family environment - the correlation for unrelated children reared together - will not include genotype-environment correlation or interaction because these children are genetically uncorrelated; thus, in terms of their genetic propensities, they will correlate and interact with the environment in ways that do not add to their resemblance. However, estimates of nonshared or shared environment derived as the remainder of phenotypic variance after other components of variance are taken into account can be affected by genotype-environment correlation and interaction because of their effects on estimates of genetic variance[35].

3.5. Model-fitting

Fitting models to adoption and twin data is a powerful way to estimate quantitative genetic parameters[36]. Although model-fitting techniques differ in their specifics, they all express family resemblance in terms of an underlying model consisting of several unobserved genetic and environmental parameters. The approach is powerful because it makes assumptions explicit, it tests a specific model, and it can incorporate into a single analysis different types of data, such as family and adoption data, rather than analyzing each type of data separately. Model-fitting procedures, however, only find significant parameters when they are implicit in the basic data: for example, in a study of adoptive siblings, a reasonable model-fitting analysis will estimate significant shared family environmental influences only if the correlation for adoptive siblings is significant. For this reason, and because of the relative inaccessibility of most models, we have emphasized the basic correlational data and merely note that model-fitting approaches confirm our conclusions.

4. Categories of nonshared environmental influence

What is happening environmentally to make children in the same family so different from one another? One gloomy prospect is that the salient environment might be unsystematic, idiosyncratic, or serendipitous events such as accidents, illnesses, and other traumas, as biographies often attest. In his autobiography, Darwin noted one example:

> The voyage of the *Beagle* has been by far the most important event in my life, and has determined my whole career; yet it depended on so small a circumstance as my uncle offering to drive me thirty miles to Shrewsbury, which few uncles would have done, and on such a trifle as the shape of my nose[37] [p. 28].

Darwin's comment about his nose refers to the quixotic captain of the *Beagle,* Captain Fitz-Roy, who nearly rejected Darwin for the trip because the shape of his nose indicated to Fitz-Roy that Darwin would not possess sufficient energy and determination for the voyage. (Darwin wrote that, during the voyage, Fitz-Roy became convinced that ''my nose had spoken falsely'' [p. 27].

It is possible that nonshared environmental influences could be unsystematic in the sense of stochastic events that, when compounded over time, make children in the same family different in unpredictable ways. Such capricious events, however, are likely to prove a dead end for research. More interesting heuristically are possible systematic sources of differences within families.

Table 1 describes categories of environmental factors that could lead to observed differences between children in the same family. These include such systematic sources of nonshared influence in the family as birth-order and gender differences of siblings, interactions between siblings, differential treatment by parents, and extrafamilial influences such as peers.

In one sense, thinking about environmental influences that create differences between children in the same family represents a dramatic reconceptualization of psychological environments. On the other hand, this reconceptualization need not involve mysterious elements in the environment: Any environmental factor can be viewed in terms of its contribution to nonshared environmental variance. For example, parental affection can be easily construed as a source of differences among children in the same family, because parents may be more affectionate toward one child than another.

Table 1 Categories of environmental influences that cause children in the same family to differ

Categories	Examples
Error of measurement	Test-retest unreliability
Nonshared environment	
Nonsystematic	Accidents, illnesses, trauma
Systematic	
Family composition	Birth-order; gender differences
Sibling interaction	Differential treatment
Parental treatment	Differential treatment
Extrafamilial networks	Peer groups; teachers; television

Source: Adapted from Rowe and Plomin[56].

In this sense, our conceptualization of nonshared environmental influence is not new and exciting. Although any traditional environmental factor can be viewed in terms of its contribution to nonshared environmental variance, it is important to emphasize the point mentioned earlier: There is no necessary relationship between environmental factors that contribute to differences between families and those that affect differences between siblings within a family. In some cases, it seems likely that there is no relationship: Socioeconomic status (SES), for example, is an important factor that operates between families, but even though the SES of families changes, it is unlikely that SES is an important source of differences between siblings. Conversely, an environmental factor that makes only a slight difference between families may be critical within families. For reasons such as these, what is needed more than speculation about the most relevant nonshared environmental influences is research identifying relevant factors. This research can at the same time provide insights into theoretical issues such as the relationship between nonshared influences and traditional environmental factors studied across families.

The perspective of nonshared environment does, however, suggest some new ways to study environmental influences. For example, we must focus on measures of experience specific to each child. That is, one implication of our conclusion concerning the importance of nonshared environment is that environmental factors shared by both children in a family are unlikely to be important sources of environmental influence. Environmental measures are needed that capture the major sources of differential experience of siblings. Another strategy for research is exemplified by the emphasis of family therapists on systems theory in which the child is viewed as part of an organized family system, creating and maintaining patterns of behavior[38]. Another strategic suggestion for the study of nonshared environment is to explore environmental sources of developmental differences *within individuals*[39]: An environmental factor that is responsible for change in a child from early childhood to school age is also likely to make children in the same family different from one another.

Finally, another, even more speculative, methodological lead for research is that subjective, perceived experiences may prove to be important[40]. For example, even if during home observations children in the same family appear to receive the ''same'' environmental treatment, this does not mean that the children experienced the treatment similarly. We do not mean to suggest that objective assessment of the environment is not also needed - it would be best to use objective and subjective measures in the same study in order to compare their relative effectiveness in predicting sibling differences. A first attempt to assess differences in perceived environments of siblings is discussed in the following section.

5. Attempts to identify nonshared environmental influences

This section explores attempts to assess specific factors within these categories that may be responsible for nonshared environmental variance. Family constellation variables, especially birth order, have been studied extensively. Other categories of possible nonshared environmental influence such as differential parental treatment, differential sibling interaction, and differential extra-familial experiences have not yet received much attention.

5.1. Birth-order

The only specific source of nonshared family environment to receive considerable attention is birth-order. For example, over 1,000 entries for ''birth-order'' appear in *Psychological Abstracts.* Birth-order is a prototype of nonshared environmental influence in that it is different for children in the same family and yet cannot originate in genetic differences among siblings. Paradoxically, however, most studies have analyzed its effect across families rather than within families and most of the relationships are weak for IQ[41] and for personality[42].

5.2. Other systematic nonshared environmental influences

Although birth-order has received considerable attention, studies of differential parental treatment, sibling interaction, and extrafamilial influences are more promising. In exploring possible nonshared influences, the first step is to ask whether siblings in a family have different experiences. If siblings do not differ in their experience for a particular aspect of the environment then that environmental factor cannot be a source of differences between them. For birth-order, this first step is unnecessary because siblings obviously differ in birth-order. Experiential differences, however, cannot be assumed to affect behavioral differences within pairs of siblings, therefore demonstrating that nonshared experiences are related to differences in sibling behavior is the second step. The third step is to describe the direction of effects when associations are found between differential experience and differences in their behaviors. Do sibling differences in experience affect or merely reflect differences in sibling behavior?

Thus, there are three steps in research on nonshared environmental influences: identifying experiences that are not shared by family members, relating such nonshared environmental factors to differences in sibling behavior, and determining the causal direction of such relationships. Because the topic of nonshared environment is so new, only a few relevant studies have been reported and most of these address the first step.

5.3. Sibling inventory of differential experience

One systematic approach to the topic is the Sibling Inventory of Differential Experience (SIDE)[43]. The 73-item self-report SIDE asks each sibling to compare his experiences to those of a sibling in the domains of sibling interaction, parental treatment, peer characteristics, and events specific to the individual. For all items, siblings are asked to compare their relative experiences rather than to make absolute judgments about their experience. For example, rather than asking the extent to which ''my sibling and I show understanding for each other,'' the SIDE asks, ''Who has shown more understanding for the other?'' A 5-point scale is used for the siblings' ratings: 1 = My sibling has been much more this way than I have; 2 = My sibling has been a bit more this way than I have; 3 = My sibling and I have been the same in this way; 4 = I have been a bit more this way than my sibling; and 5 = I have been much more this way than my sibling. This provides relative scores indicating, for example, the extent to which one sibling feels he is understood by the other. Although somewhat unusual, these relative judgments have several advantages. First, they should be easier to make than absolute judgments - for example, on a 5-point scale, how much do you understand your sibling? (compared to what?). Second, relative judgments do not require that a sibling difference be calculated in order to assess nonshared environment. Third, they can be used when data are available from only one member of a sibling pair. The SIDE can also be coded to indicate the absolute rather than relative amount of differential sibling experience by disregarding the direction of the differential experience (i.e., 0 = no difference in sibling experiences; 1 = some difference; 2 = much difference).

Table 2 Scales of nonshared environmental influence from the Sibling Inventory of Differential Experience (SIDE)

Category	Scale	Test-retest reliability	Sibling agreement
Sibling interaction	Differential Sibling Antagonism	.83	.39
	Differential Sibling Jealousy	.93	.56
	Differential Sibling Caretaking	.89	.56
	Differential Sibling Closeness	.70	.23
Parental treatment	Differential Maternal Affection	.82	.26
	Differential Maternal Control	.77	.25
	Differential Paternal Affection	.77	.28
	Differential Paternal Control	.85	.49
Peers	Differential Peer College Orientation	.88	.55
	Differential Peer Delinquency	.94	.73
	Differential Peer Popularity	.84	.60

Source: Adapted from Daniels and Plomin[43].

The 11 scales of the SIDE (see Table 2) were devised using the results of factor analyses of data on a sample of 396 12- to 28-year-old siblings from the Denver metropolitan area. The word ''differential'' precedes the label for each scale to emphasize that all items involve relative (differential) ratings. The 2-week, test-retest reliabilities are reasonable, with a mean of .84 and a range from .70 to .94. The scales are virtually independent of sibling's age, birth-order, and gender. Also included in the table are sibling agreement correlations which indicate that siblings agree quite substantially, especially in the areas of differential sibling interaction and peer group characteristics. The sibling agreement correlations are .55, .73, and .60 concerning which sibling's peer group was more college oriented, delinquent, and popular, respectively. Siblings also agree substantially as to which sibling was more jealous ($r = .56$) and which sibling displayed more caretaking ($r = .56$). Siblings agree to a lesser extent on differences in parental treatment ($r = .26$ and .28 for maternal and paternal affection). The median sibling agreement correlation over the 11 SIDE scales is .49, which is above typical interrater agreement on personality and environmental paper-and-pencil measures. The high sibling agreement found for some of the SIDE scales may be due to the fact that siblings are asked to make a relative and specific comparison to their sibling rather than an absolute judgment in comparison to all other children of that age. Because the SIDE intentionally assesses siblings' perceptions of their differential experience, sibling agreement is not an important criterion for the usefulness of the measure as long as the measure is reliable. Other substantive findings from the SIDE are interwoven throughout the following discussion on the major categories of systematic nonshared environment.

5.4. Parental treatment

Environmental research has traditionally focused on parental treatment because parents appear first and foremost in young children's lives. It has not been easy, however, to document parental effects on children's development. A recent review of the relationship between parental treatment and children's development concludes that ''in most cases, the relationships that have appeared are not large, if one thinks in terms of the amount of variance accounted for''[32] [p. 82]. Indeed, these findings led the authors to argue for the need to examine intrafamilial variation in the parent-child relationship. It should be reiterated that the importance of nonshared environment does not denigrate the importance of environmental influence. Environmental influence is important but it operates differently from the way we thought it operated. In the case of parental influences, the effect that parents have on their children has little to do with those aspects of parenting that are experienced similarly by two children in their family. Whatever these parental influences might be, they differentiate rather than integrate the children. Parenting is likely to be an important source of environmental variance only if parents differentiate their children.

How similarly or differently do parents treat their offspring? The SIDE data indicate that siblings perceive their parents to treat them quite similarly: Only 9% of siblings report ''much difference'' and 35% report ''a bit of difference'' in their parents' treatment on the average across parental treatment items. For the four SIDE scales that assess parental treatment, the mean absolute score is .50 (0 refers to no reported difference in sibling experiences, 1 indexes some difference, and 2 indicates much difference). Other categories of nonshared environmental influence show greater differentiation within sibling pairs and are thus more likely to be important sources of nonshared environmental influence. Nonetheless, it is possible that small differences in siblings' perceptions of their parents' treatment lead to large differences in their development.

Another study of adolescent siblings found similar results, not just for adolescents reports of their

Table 3 Sibling intraclass correlations for environmental measures in the national survey of children sample

Environmental measure	Parental ratings	Sibling ratings
Family cooperation	–	.17*
Family stress	–	.29*
Parental rule expectations	–	.18*
Parental chore expectations	.49*	.21*
Maternal closeness	.38*	.19*
Paternal closeness	.49*	.26*
Child's say in decisions	.65*	.18

Note: $N = 299–348$ sibling pairs. $^{*}P < .05$.
Source: Adapted from Daniels, Dunn, Furstenberg and Plomin[44]

parents' treatment, but also for the parents' reports of their treatment of their children[44]. The 1981 follow-up of the longitudinal National Survey of Children[45] included 348 families with two siblings 11 to 17 years of age (mean age = 13.7 years) from a nationally representative sample of 1,077 families. In telephone interviews, each sibling and mother was interviewed individually concerning family cooperation, family stress, parental rule and chore expectations, closeness to mother and father, and child's say in decisions. In contrast to the SIDE study, the ratings of environment in this study are absolute in that parents and siblings were not asked to rate parental treatment as it differed for the two siblings. Sibling intraclass correlations for the measures of parental treatment, as rated by parents and by the siblings themselves, are listed in Table 3. The sibling correlations indicate the extent to which parents and siblings themselves perceive that siblings share similar parental treatment. These data indicate that parents perceive that they treat their two children quite similarly - the sibling correlations range from .38 to .65. In contrast, the siblings do not perceive that their parents' treatment of them is highly similar - the sibling correlations average about .20.

Two twin studies using ''absolute'' ratings of adolescents' perceptions of parental treatment[46,47] have found substantial correlations within twin pairs for parental treatment. Different measures of parental affection and control were used in the two twin studies, and twin correlations of about .45 emerged. Parents appear to treat children less similarly in this study, which used absolute ratings, than in the SIDE research, which used ''relative'' ratings. It is reasonable, however, that sibling correlations for absolute ratings of parental treatment are lower than those for relative ratings, because the absolute rating procedure asks each sibling to rate his parents' treatment in relation to all other parents; differences between the siblings' responses are used to compute a correlation. The relative approach is more direct for assessing differences in siblings' experiences because it asks them about parental treatment specifically in comparison to their sibling.

Two analyses of sibling data in the Colorado Adoption Project include the first ''objective'' data concerning differential parental behavior towards siblings. Sibling correlations were reported for the interview/observation measure, HOME Observation for Measurement of the Environment (HOME)[48], for 133 sibling pairs in which both members of each pair were studied at 12 months of age and 103 sibling pairs were studied at 24 months[23]. The average sibling spacing was nearly 3 years, nonetheless the sibling correlations for the HOME were nearly as great as the stability of the HOME measure for all individuals from 12 to 24 months. Using the HOME data when each sibling was 12 months old, the sibling correlation for a general factor of the HOME was .42; at 24 months, it was .43. Sibling correlations at 12 months for the Family Environment Scales (FES)[49] also approached the 1-year stability of the measure. The FES is not at all specific to a particular child, however, because it assesses the general social climate of the home; the HOME is only somewhat specific to each child - some items, such as number of books present and visible, are likely to be similar for all children in the family.

The most impressive results suggesting that parents treat their several children similarly comes from a longitudinal study of 50 families in which mothers were videotaped while interacting individually with each of two siblings when each child was 12 months old[33]. The children were nearly 3 years apart in age, which means that the observations of maternal behavior toward the two children were separated by nearly three years. Maternal behavior was reliably assessed, and factor analysis yielded three factors: affection, verbal attention, and control. The results indicate that the mothers were remarkably consistent in their behavior toward their two children at the same age: Corrected for unreliability, the average correlation for maternal behavior toward two siblings was .70. These data suggest that differential maternal treatment of their children in infancy does not appear to be a major source of the marked individual differences within pairs of siblings. Other longitudinal studies on this topic agree that mothers are quite consistent in their behavior toward two of their children when the children are studied at the same age[50,51,52].

Nontwin siblings are in fact different in age. Subsequent work by Dunn and her colleagues has indicated that even though mothers treated their two children quite similarly when the children were the same age, longitudinal analyses from 12 to 24 months showed little stability for maternal behavior to the same child. The authors suggest that rank-order of the mothers on these dimensions changes from 12 to 24 months because different mothers respond differently to the new developmental advances of children. Analyses from a study using a very different methodology - extensive and intensive unstructured home observations of a sample of 80 British families - support the same interpretation[53]. Individual differences in maternal responsiveness that were highly stable during the first year of life changed markedly with the developments in the children's communicative abilities in the second year. Similarly, in another study, correlations between 12 and 24 months in measures of maternal physical, affectionate, verbal, visual, and responsive behavior were very low: −.05, .05, .05, .04, and .17, respectively[54].

The implication of these results is that in a cross-sectional slice of time siblings differ in age and are treated quite differently. Thus, the possible effect of differential parental treatment on siblings of different age needs further exploration.

In summary, sibling reports, parental self-reports, and observational studies yield no clear conclusion concerning differential parental treatment. To the extent that parents treat their children similarly, we would not expect parental treatment to be a major source of nonshared environmental influence, although, as mentioned earlier, it is possible that small differences in parental treatment lead to large differences in development.

5.5. Sibling Interaction

The possibility that siblings' interactions with each other are a source of nonshared environmental influences has not been studied nearly as much as parental treatment. It is noteworthy, however, that the results of intensive observational studies of mother-sibling-sibling triads emphasize the importance of sibling-sibling interactions[55,51] Twin data on sibling interaction have been reported for 88 pairs of high-school twins[56]. For a Liking scale, the correlation for all 88 pairs was .61, indicating that twins liking and disliking of each other is mutual. Twins generally like each other though (the average response was 4.4 on a 5-point scale), which means that this result involves only a small amount of variance. Two other scales, Respect and Understanding, yielded more variance than the Liking scale, and twin correlations of .35 and .30, respectively, indicated considerable differences within pairs of twins. These twin correlations for twins' respect for and understanding of each other are lower than those found in Rowe's studies of twins' perceptions of their parents' treatment, thus suggesting that siblings might provide more nonshared environment than do parents.

The SIDE explores sibling interaction with scales that assess differential sibling antagonism, caretaking, jealousy, and closeness. As indicated earlier, only 9% of 396 siblings reported ''much difference'' in their parents treatment on the average and the mean absolute score is .50. In contrast, 19% of the siblings report ''much difference'' and 40% report ''a bit of difference'' in their siblings' treatment of them; the mean absolute score is .80[43].

In summary, although a few relevant studies have been reported, some data suggest that each member of a sibling pair may provide a substantially different environment for the other member of the pair, especially when the data are based on adolescents' self-reported perceptions. In terms of components of variance, one might predict that, to the extent that siblings affect one another, the variance of individuals who are siblings should exceed the variance of individuals who are singletons. We are not aware of any tests of this prediction. However, there may be other factors diluting this variance difference between siblings and singletons - for example, it is not implausible to suggest that parents of siblings have less of an effect on each of their children than do parents of singletons.

5.6. Peer characteristics

Even less is known about extra-familial sources of nonshared environment such as peers. The only report of peers as a possible source of differential experience for siblings is based on the SIDE[43]. For the 26 peer characteristic items, 20% of the siblings report ''much difference'' and 42% report ''a bit of difference'' in their peer groups' characteristics. The mean absolute score is .83 for the three peer scales of the SIDE, which suggests that siblings experience peer differences as great as the differences they experience in their interaction with each other.

6. Relationships between nonshared factors and sibling differences in behavior

The first question in studies of nonshared environmental influences is whether such factors exist. The answer is clearly affirmative: Siblings in the same family experience different environments, perhaps with respect to parental treatment, and probably in their interaction with each other and in characteristics of their peer groups. The next question is whether these differences in experience are related to differences in behavioral development.

The study of adolescent siblings from the National Survey of Children[43] related differential parental treatment to differences in sibling adjustment. As in all studies of personality and psychopathology, the siblings were only moderately similar for adjustment, with correlations of about .20, which means that the great majority of reliable variance is not shared by siblings. Table 4 lists multiple regression coefficients when sibling differences in adjustment measures are regressed on several of the sibling differences in environment listed in Table 3.

Most of the multiple regressions are significant, and adjusted R^2 values of about 10% on the average

Table 4 Multiple regressions of differences in sibling adjustment on differences in sibling environments

Adjustment measure[a]	Multiple *R*'s	
	Parental ratings of sibling differences in experience	Sibling ratings of sibling differences in experience
Parental report of emotional distress	.38*	.25
Parental report of delinquency	.37*	.25
Parental report of disobedience	.37*	.26
Self report of emotional distress	.12	.28*
Self-report of delinquency	.29*	.37*
Self-report of dissatisfaction	–[b]	.35*
Teacher report of disobedience	–[b]	.35*
Parent-sibling-teacher aggregate score of disobedience	.40*	.34*

[a]The multiple regressions involve sibling difference scores for each adjustment measure.
[b]Not available.
*$P < .05$.
Source: Adapted from Daniels, Dunn, Furstenberg, and Plomin[44].

indicate that nonshared environmental influences are systematically related to differences in the siblings' adjustment. For example, the last row of Table 4 shows associations between nonshared environment and an aggregate measure of disobedience based on parent, sibling, and teacher ratings. The significant regressions indicate that for both parental and sibling ratings of sibling experience differential experiences of siblings are related to differences in disobedience. It is noteworthy that some significant relationships emerge when different individuals rate the siblings' adjustment and the siblings' environment. For example, parental perceptions of sibling differences in environment are related to differences in the siblings' own perception of delinquency, and sibling perceptions of environmental differences are related to teacher ratings of disobedience. With regard to the specific environmental differences that relate to sibling differences in the adjustment measures, both the parent and sibling reports of the environment converge on the finding that the sibling who experiences more maternal closeness, more sibling friendliness, more say in family decision making, and more parental chore expectations, as compared to the other sibling, is better adjusted psychologically.

Other studies that relate differential sibling experience to differences in the siblings' behavior have been reported; however, these studies have used twin and adoption designs to test the possibility that such relationships are mediated genetically. For this reason, these studies are described in the following section.

7. Direction of effects

Once relationships are identified between any environmental factor and behavior, one can address the issue of direction of effects: Does the environmental factor affect or merely reflect differences among individuals?[57] The direction-of-effects issue is just as relevant to the study of nonshared environmental influences as it is in traditional studies. For example, differential parental affection might be related to differences in the siblings' sociability because preexisting differences in the siblings' sociability elicit differences in their parents' affection toward them.

Behavioral-genetic designs can be profitably applied to this issue because one possible explanation for a child-to-environment direction of effects is genetic differences between the siblings. That is, siblings might report differences in treatment that occur as a result of genetic differences between them. Finding genetic influence on a nonshared environmental measure suggests that genetic differences between the siblings underlies, at least in part, their experiential differences. There are two subsidiary issues: Do measures of nonshared environment show genetic influence? Are relationships between measures of nonshared environment and measures of behavior mediated genetically?

It should be noted that failure to find genetic influence does not prove that the measured nonshared environmental influence causes behavioral differences within pairs. It is possible, for example, that behavioral differences within pairs of siblings originate from prior experiences with which the contemporaneous measure of nonshared environment is correlated.

7.1. Do measures of nonshared environment show genetic influence?

One study[43] exists that explored the origins of differential sibling experience. SIDE data from 222 adoptive siblings were compared to data from 174 biological siblings. If the SIDE reflects genetic differences, mean SIDE differences should be greater for adoptive than for biological pairs because adoptive siblings are uncorrelated genetically in the absence of selective placement, whereas biological siblings correlate .50 genetically. Samples of this size have 80% power to detect mean differences in experience that account for as little as 2% of the variance. In general, the SIDE measures of differential experience were similar for adoptive and nonadoptive siblings: Average correlations were .76 for adoptive siblings and .69 for biological siblings. Thus, the SIDE scales on average suggest negligible genetic influence, which implies that the origins of perceived differential experience are indeed environmental. However, 4 of the 11 SIDE scales yielded significantly greater differences for adoptive siblings than for biological siblings that accounted for 4%-12% of the variance, thus suggesting slight genetic influence for some of the SIDE scales.

Finding little genetic influence on the SIDE measure is both surprising and interesting because behavioral genetic studies of most behavioral traits and of *shared* environmental measures do show considerable genetic influence[7]. Although replication of this finding is necessary, it may be that differential experiences of siblings are in fact insensitive to genetic differences between the siblings. Because siblings are asked to make relative comparisons to their other sibling on the SIDE, this micro-analysis may go beyond the genetic make-up of family members. Regardless of the explanation, it is noteworthy that this first study of the etiology of nonshared environment as assessed by the SIDE shows little evidence of genetic influence.

7.2. Are relationships between nonshared environment and behavior mediated genetically?

Thus, one set of data has implied that nonshared environmental influences may be virtually uncontaminated by hereditary influences. If a measure of nonshared environment is not influenced by heredity, its relationship to behavioral differences is unlikely to be mediated genetically. Nonetheless, because so little work has been done in this area, it is important to ask the next question: whether genetic differences on measures of nonshared environment (assessed directly by the SIDE or indirectly through sibling difference scores on shared environment measures) are translated into behavioral differences between siblings. The possibility of genetic mediation of relationships between environment and behavior has recently been discussed[58], although not in the context of nonshared environmental influences.

One way to study nonshared environment free of genetic bias is to relate experiential differences within pairs of identical twins to behavioral differences within the twin pairs. Because identical twins share exactly the same heredity, environmental and behavioral differences within pairs cannot be explained by genetic differences. Twin studies can also assess possible genetic influences by comparing the relationship between experiential and behavioral differences within identical twin pairs to the relationship within fraternal twin pairs. If heredity is influential, the correlations will be greater for fraternal twins than for identical twins because differences within pairs of fraternal twins are due to genetic differences as well as nonshared environmental influences. Although this approach has not been used systematically, a study by Rowe and Plomin[56] examined the relationship between differences in interpersonal treatment of the twins and differences in self-reported personality. The authors noted that the relationships between twin differences in the measures of nonshared environment and twin differences in the measures of personality were generally weak for both identical and fraternal twins. The fact that the fraternal twin correlations were no greater than the identical twin correlations suggests that what little relationship exists between nonshared environment (as measured in this study in terms of the twins' perceptions of their interpersonal relationship) and personality does not appear to be mediated by heredity.

As mentioned earlier, twins probably share more environmental influences than do nontwin siblings. For this reason, the twin method is not a powerful approach to the study of relationships between nonshared environmental influences and behavioral differences. That is, twins may experience more similar environments and be more similar behaviorally than nontwin siblings. Another method that is less direct but might prove to be more generalizable to the nontwin situation is to compare correlations between nonshared environmental differences and behavioral differences for pairs of adoptive and nonadoptive siblings. Behavioral differences within pairs of nonadoptive siblings could be either genetic or environmental in origin because first-degree relatives are 50% similar genetically. In the absence of selective placement, however, adoptive sibling pairs do not resemble each other genetically. Thus, if the relationship between nonshared environmental measures and differences in sibling behaviors reflects genetic differences within pairs of siblings, we would expect correlations for sibling differences in environment and in behavior to be greater for adoptive siblings than for nonadoptive siblings.

A recent study of adoptive and nonadoptive infant siblings in the Colorado Adoption Project explored this issue[23]. Although no measure designed specifically to assess differential sibling experiences was used, the HOME and FES were included. As mentioned earlier, the results suggested little differential experience for two siblings when each sibling's environment was assessed separately at the time the child was 12 months of age. However, even these slight differential experiences of the siblings as assessed by the HOME and FES showed some association (r's = .2–.3) with behavioral differences between the infant siblings. For hundreds of comparisons between sibling differences on the HOME and FES and various sibling behavioral differences, over 13% were significant. For example, at 12 months, differences in the extent to which mothers consciously encouraged developmental advance (as measured by the HOME) correlated .31 with differences in the siblings' activity level (as assessed by the tester using the Infant Behavior Record). More to the point, this study showed only environmental mediation in that no differences were found between correlations for adoptive and nonadoptive sibling pairs.

In the only other study examining nonshared environment-behavior relationships, the SIDE scales were related to adolescent sibling personality differences[59]. In this study of adoptive and nonadoptive siblings, no genetic influence was detected, even though the SIDE accounted for 6%–26% of the variance of sibling personality difference scores. For example, the sibling who experienced more sibling closeness and peer popularity also reported more sociability as compared to his sibling; the sibling who reported more sibling jealousy and peer delinquency also reported more emotionality as compared to his sibling. Although longitudinal work is necessary to address the direction of effects in these relationships, it can at least be said that genetically influenced personality differences between the siblings do not lead to differences in their interactions with siblings and peers.

In summary, the results of these two studies suggest that, at least in infancy, heredity does not importantly mediate relationships between siblings' experiential differences and differences in their behavior. A reasonable priority for research would be to identify relationships between nonshared environment and sibling differences in behavior using nontwin siblings in nonadoptive families and to worry about the direction of effects only after such relationships are found.

8. Implications and conclusions

In this target article we have presented evidence that converges on the conclusion that children in the same family experience practically no shared environmental influence that makes them similar for behavioral traits. In other words, the effective environments of siblings are hardly any more similar than are the environments of strangers who grow up in different families. This conclusion has been put particularly forcefully by Scarr and Grajek[60] [p. 361].

> Lest the reader slip over these results, let us make explicit the implications of these findings: Upper middle-class brothers who attend the same school and whose parents take them to the same plays, sporting events, music lessons, and therapists, and use similar child rearing practices on them are little more similar in personality measures than they are to working class or farm boys, whose lives are totally different. Now, perhaps this is an exaggeration of the known facts, but not by much. Given the low correlations of biological siblings and the near zero correlations of adopted siblings, it is evident that most of the variance in personality arises in the environmental differences among siblings, *not* in the differences among families.

This unsettling fact is rich in implications for research, theory, and application. In terms of research implications, studies of the family environment and socialization can take advantage of the key of nonshared environment by studying more than one child per family in order to identify environmental factors that make children in a family so different from one another. Recent studies presented in this review indicate that this is a promising area for research.

The importance of nonshared environment also suggests the need for a theoretical reeonceptualization of environmental influences in development. Most important, the child rather than the family must be considered the unit of socialization. The search for nonshared environmental influences will be aided by theories of the processes by which nonshared environment can lead to developmental differences between siblings. Nearly every psychological theory - including learning, psychoanalytic, Piagetian, ethological, biopsychological, family-system, and social-psychological theories - has something to offer when viewed from the perspective of nonshared environment. To mention but a few examples, learning theory offers sibling conditioning and modeling as processes by which nonshared environment may leave its mark; sibling deidentification and split-parent identification have emerged from psychoanalytic theory[61]; social psychology could offer contrast effects and attribution differences as possible mediators of nonshared experience. Developing a coherent theory of the processes by which nonshared experience lead to differences between children in the same family is a high priority for the area.

Our new knowledge concerning the importance of nonshared environment may have its deepest implications for intervention. The data are descriptive, not proscriptive. That is, they indicate that, of the variability that exists in children's environments, the portion of the environmental variability that affects children's psychological development is nearly exclusively of the nonshared variety. It does not mean that shared environmental factors cannot or should not affect the development of children. Nonetheless, it is critical for interventionists to know, for example, that what parents do that is experienced similarly by their children does not have an impact on their behavioral development. If the effects of parents on their children lie in the unique environments they provide for each child, childrearing books need to be rewritten, and early childhood education and interventions aimed at the prevention of psychopathology need to be rethought. The importance of nonshared environments, as it works both systematically and stochastically, implies that the environmental impact on children works through the power of differentiation within the family. The possibly subtle differences experienced or perceived by children in the same family are the environmental factors that drive behavioral development.

In conclusion, although it was less than a decade ago that the importance of nonshared environmental influences was brought to the attention of behavioral scientists, the results of research in this area have led to the following conclusions:

(1) Behavioral-genetic studies consistently point to nonshared environment as the most important source of environmental variance for personality, psychopathology, and IQ after childhood.
(2) When more than one child is studied per family, it is apparent that siblings in the same family experience considerably different environments, in terms of their treatment of each other, in their peer interactions, and perhaps in terms of parental treatment.
(3) Family composition variables such as birth-order and gender differences account for only a small (1%–5%) portion of the variance of sibling differences in development.
(4) Differences in siblings' experiences relate significantly to siblings' differences in behavior, implying that nonshared environmental influences arc at least in part systematic.
(5) Measures of nonshared environment do not primarily reflect genetic differences between children in the same family.

The first conclusion is the strongest: Nonshared environment is a major part of the answer to the question posed in the title of this article. The other conclusions are better viewed as initial hypotheses for future research. Despite this attempt to impose some order on the results of the few extant studies of nonshared environment, questions are certainly more obvious than answers. A crucial question is whether most nonshared environmental variance is systematic. Other questions emerge from the recognition that nonshared environmental influences and their effects on behavioral development are likely to be specific: Which specific nonshared environmental factors account for most variance? Which sibling differences in behavior are most strongly related to specific nonshared influences? Is there a general theory predicting these relationships? What are the developmental provenances and processes of specific nonshared environmental factors and their relationship to behavioral differences between children in the same family?

A few faltering first steps have been taken toward exploring nonshared environmental influence. A long road lies ahead but, because most of the environmental variance that affects behavioral development is of the nonshared variety, this is surely an important road to travel.

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References

[1] Falconer DS. *Introduction to quantitative genetics*. Longman, 1981.

[2] Hay DA. *Essentials of behaviour genetics*. Blackwells, 1985.

[3] Plomin R, DeFries JC, McClearn GE. Behavioral genetics: A primer. *Freeman* 1980.

[4] Fisher RA. The correlation between relatives on the supposition of Mendelian inheritance. *Transactions of the Royal Society of Edinburgh* 1918;**52:**399–433.

[5] Ozer DJ. Correlation and the coefficient of determination. *Psychological Bulletin* 1985;**97:**307–315.

[6] Lykken DT. Research with twins: The concept of emergensis. *Psychophysiology* 1982;**19:**361–73.

[7] Plomin R. *Development, genetics, and psychology*. Erlbaum, 1986.

[8] Loehlin JC, Nichols RC. *Heredity, environment, and personality*. University of Texas Press, 1976.

[9] Goldsmith HH. Genetic influences on personality from infancy to adulthood. *Child Development* 1983;**54:**331–55.

[10] Eysenck HJ. The biological basis of personality. Charles C. Thomas, 1967.

[11] Cattell RB, Eber H, Tatsuoka MM. Handbook for the Sixteen Personality Factor questionnaire. *Institute for Personality and Ability Testing* 1970.

[12] Floderus-Myrhed B, Pederson N, Rasmuson S. Assessment of heritability for personality based on a short form of the Eysenck Personality Inventory. *Behavior Genetics* 1980;**10:**153–62.

[13] Lykken DT, Tellegen A, DeRubeis R. Volunteer bias in twin research: The rule of two-thirds. *Social Biology* 1978;**25:**1–9.

[14] Loehlin JC. Are personality traits differentially heritable? *Behavior Genetics* 1982;**12:**417–28.

[15] Buss AH, Plomin R. *Temperament: Early developing personality traits*. Erlbaum, 1984.

[16] Plomin R, Foch TT. A twin study of objectively assessed personality in childhood. *Journal of Personality and Social Psychology* 1980;**39:**680–88.

[17] Crook MN. Intra-family relationships in personality test performance. *Psychological Record* 1937;**1:**479–502.

[18] Ahern FM, Johnson RC, Wilson JR, McClearn GE, Vandenberg SC. Family resemblances in personality. *Behavior Genetics* 1982;**12:**261–80.

[19] Loehlin JC, Horn JM, Willerman L. Personality resemblance in adoptive families. *Behavior Genetics* 1981;**11:** 309–30.

[20] Loehlin JC, Willerman L, Horn JM. Personality resemblance in adoptive families when the children are late adolescents and adults. *Journal of Personality and Social Psychology* 1985;**48:**376–92.

[21] Scarr S, Webber PI, Weinberg RA, Wittig MA. Personality resemblance among adolescents and their parents in biologically related and adoptive families. *Journal of Personality and Social Psychology* 1981;**40:**885–98.

[22] Scarr S, Weinberg RA. Attitudes, interests, and IQ. *Human Nature* 1978;29–36.

[23] Daniels D. *Understanding the family environment: A study of adoptive and nonadoptive infant siblings. Unpublished doctoral dissertation*. University of Colorado, 1985.

[24] Bayley N. Manual for the Bayley Scales of infant development. *Psychological Corporation* 1969.

[25] Gottesman II, Shields J. *Schizophrenia: The epigenetic puzzle*. Cambridge University Press, 1982.

[26] Fuller JL, Thompson WR. Foundations of behavior genetics. *Mosby* 1978.

[27] Rosenthal D. *Genetic theory and abnormal behavior*. McGraw-Hill, 1970.

[28] Bouchard TJ Jr, McGue M. Familial studies of intelligence: A review. *Science* 1981;**212:**1055–59.

[29] Kent J. *Genetic and environmental contributions to cognitive abilities as assessed by a telephone test battery. Unpublished doctoral dissertation*. University of Colorado, 1985.

[30] DeFries JC, Fulker DW. Multiple regression of twin data. *Behavior Genetics* 1985;**15:**467–73.

[31] Jinks JL, Fulker DW. Comparison of the biometrical genetical, MAVA and classical approaches to the analysis of human behavior. *Psychological Bulletin* 1970; **73:**311–49.

[32] Maccoby EE, Martin JA. Socialization in the context of the family: Parent-child interaction. In: Mussen PH (ed.). *Handbook of child psychology (4th ed.). Socialization personality, and social development*. Wiley, 1983.

[33] Dunn JF, Plomin R, Nettles M. Consistency of mothers' behavior towards infant siblings. *Developmental Psychology* 1985;**21:**1188–95.

[34] Dunn JF, Plomin R, Daniels D. Consistency and change in mothers' behavior towards young siblings. *Child Development* 1986;**57:**348–56.

[35] Plomin R, DeFries JC, Loehlin JC. Genotype-environment interaction and correlation in the analysis of human behavior. *Psychological Bulletin* 1977; **84:**309–22.

[36] Loehlin JC. Heredity-environment analysis of Jeneks's IQ correlations. *Behavior Genetics* 1978;**8:**415–36.

[37] Darwin C. In: Darwin F (ed.). *The autobiography of Charles Darwin and selected letters*. Dover, 1892.

[38] Minuchin P. Families and individual development: Provocations from the field of family therapy. *Child Development* 1985;**56:**289–302.

[39] McCall RB. Environmental effects on intelligence: The forgotten realm of discontinuous nonshared within-family factors. *Child Development* 1983;**54:**408–15.

[40] Jessor R. The perceived environment in psychological theory and research. In: Magnusson D (ed.). *Toward a psychology of situations: An interactional perspective*. Erlbaum, 1981.

[41] Galbraith RC. Sibling spacing and intellectual development: A closer look at the confluence models. *Developmental Psychology* 1982;**18:**151–73.

[42] Ernst C, Angst J. *Birth order: Its influence on personality*. Springer-Verlag, 1983.

[43] Daniels D, Plomin R. Differential experience of siblings in the same family. *Developmental Psychology* 1985;**21:** 747–60.

[44] Daniels D, Dunn J, Furstenberg FF Jr, Plomin R. Environmental differences within the family and adjustment differences within pairs of adolescent siblings. *Child Development* 1985;**56:**764–74.

[45] Furstenberg FF Jr, Winquist-Nord C, Peterson JL, Zill N. The life course of children of divorce. *American Sociological Review* 1983;**48:**656–68.

[46] Rowe DC. Environmental and genetic influences on dimensions of perceived parenting: A twin study. *Developmental Psychology* 1981;**17:**203–8.

[47] Rowe DC. A biometrical analysis of perceptions of family environment: A study of twin and singleton sibling kinships. *Child Development* 1983;**54:**416– 23.

[48] Caldwell BM, Bradley RH. *Home observation for measurement of the environment*. University of Arkansas, 1978.

[49] Moos RH, Moos BS. *Family Environment Scale manual*. Consulting Psychologists Press, 1981.

[50] Abramovitch R, Pepler D, Corter C. Patterns of sibling interaction among preschool-age children. In: Lamb M, Sutton-Smith B (eds). *Sibling relationships: Their nature and significance across the lifespan*. Erlbaum, 1982.

[51] Dunn JF, Kendrick C. Siblings: Love, envy, and understanding. *Grant McIntyre* 1982.

[52] Jacobs BS, Moss HA. Birth order and sex of sibling as determinants of mother-infant interaction. *Child Development* 1976;**47:**315–22.

[53] Dunn J. Patterns of early interaction: Continuities and consequences. In: Schaffer HR (ed.). *Studies in mother-infant interaction*. Academic Press, 1977.

[54] Clarke-Stewart KA, Hevey CM. Longitudinal relations in repeated observations of mother-child interaction from 1 to 2½ years. *Developmental Psychology* 1981;**17:**127–45.

[55] Dunn J. Sibling relationships in early childhood. *Child Developments* 1983;**54:**787–811.

[56] Rowe DC, Plomin R. The importance of nonshared (EI) environmental influences in behavioral development. *Developmental Psychology* 1981;**17:**517–31.

[57] Bell RQ. A reinterpretation of the direction of effects in socialization. *Psychological Review* 1968;**75:**81–95.

[58] Plomin R, Loehlin JC, DeFries JC. Genetic and environmental components of ''environmental'' influences. *Developmental Psychology* 1985;**21:**391–402.

[59] Daniels D. Sibling personality differences and differential experience of siblings in the same family. *Journal of Personality and Social Psychology* 1986;**51:** 339–346.

[60] Scarr S, Grajek S. Similarities and differences among siblings. In: Lamb ME, Sutton-Smith B (eds). *Sibling relationships: Their nature and significance across the lifespan*. Erlbaum, 1982.

[61] Schachter FF. Sibling deidentification and split-parent identification: A family tetrad. In: Lamb ME, Sutton-Smith B (eds). *Sibling relationships: Their nature and significance across the lifespan*. Erlbaum, 1982.

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Commentary: Why are children in the same family so different? Non-shared environment three decades later

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Introduction

The importance of non-shared environment lay hidden within quantitative genetic studies since they began nearly a century ago. Quantitative genetic methods, such as twin and adoption methods, were designed to tease apart nature and nurture in order to explain family resemblance. For nearly all complex phenotypes, it has emerged that the answer to the question of the origins of family resemblance is nature—things run in families primarily for genetic reasons. However, the best available evidence for the importance of environmental influence comes from this same quantitative genetic research because genetic influence never explains all of the variance for complex phenotypes, and the remaining variance must be ascribed to environmental influences.

Yet it took many decades for the full meaning of these findings to emerge. If genetics explains why siblings growing up in the same family are similar, but the environment is important, then it must be the case that the salient environmental effects do not make siblings similar. That is, they are not shared by children growing up in the same family—they must be 'non-shared'. This implication about non-shared environmental import lay fallow in the field of quantitative genetics because the field's attention was then firmly on the nature–nurture debate. 'Nurture' in the nature–nurture debate was implicitly taken to mean shared environment because from Freud onwards, theories of socialization had assumed that children's environments are doled out on a family-by-family basis. In contrast, the point of non-shared environment is that environments are doled out on a child-by-child basis. Note that the phrase 'non-shared environment' is shorthand for a component of phenotypic variance—it refers to 'effects' rather than 'events', as discussed later.

The 1987 paper reprinted in this issue of the *International Journal of Epidemiology*[1] brought together evidence for the importance of non-shared environment in the development of personality, psychopathology and cognitive abilities, expanding on a previous paper.[2] The purpose of the present commentary is to reflect on non-shared environment three decades after the topic emerged. Progress and problems in studying non-shared environment were reviewed in 2001;[3] rather than providing a systematic update of this burgeoning field, my current goal is to suggest some new directions for research in this area.

The 1987 paper was published with 32 commentaries and our response,[4] which I recommend. These commentaries and the response to them raised many of the issues that resurfaced during the following decades, such as the following:

- Non-shared environmental effects need to be distinguished from error of measurement (yes).
- Non-additive genetic variance can account for non-shared environmental effects (no).