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A Behavioural Genetic Analysis Of Personality, Personality Disorder, The Environment, And The Search For Sources Of Nonshared Environmental Influences

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A BEHAVIOURAL GENETIC ANALYSIS OF PERSONALITY, PERSONALITY DISORDER, THE ENVIRONMENT, AND THE SEARCH FOR SOURCES OF NONSHARED ENVIRONMENTAL INFLUENCES

by

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ABSTRACT

A behaviour genetic analysis of personality, liability to personality disorder, and the general environment of siblings was conducted using a classic twin study design. A sample of 138 same-sex young adult twin pairs (89 monozygotic pairs, 49 dizygotic pairs) was used to estimate trait variance attributable to direct gene action (h^2_A), shared environmental experiences (c^2), and nonshared environmental experiences (e^2). Paralleling previously published results, model-fitting heritability analyses of the Personality Research Form (PRF; Jackson, 1986), and the Minnesota Multiphasic Personality Inventory, (MMPI, Hathaway & McKinley, 1983) showed that additive genetic and nonshared environmental factors could satisfactorily account for the trait variance in personality. Additional analyses revealed that genetic dominance effects (d^2) were present but are of a negligible magnitude. Multivariate genetic analyses also showed that there is evidence for a common genetic and environmental etiology to some dimensions of normal personality and liability to personality disorder.

Simple heritability analyses were also applied to four measures of the environment: Sibling Inventory of Differential Experience (SIDE; Daniels and Plomin, 1985), the Environmental Response Inventory (ERI; McKenchie, 1974), the Family Environment Scale (FES; Moos and Moos, 1986), and the Classroom Environment Scale (CES: Trickett and Moos, 1974). With the exception of the CES and specific scales from the SIDE, most of the remaining scales showed substantial additive genetic influence. However, the degree of genetic influence was found to be smaller than that reported in some previous studies.

Finally, a series of analyses was conducted with twins and an additional sample of 65 same-sex non-twin sibling pairs (51 sister-pairs, 14 brother-pairs) designed to identify sources of nonshared environmental influence related to differential personality and liability to personality disorder. Absolute differences in sibling personality as measured by the PRF and MMPI were regressed on absolute differences in sibling experience as measured by the SIDE, FES, CES, and ERI. Overall, only a few significant predictors of differential personality were found. Parental treatment and peer delinquency variables emerged as predictors of liability to personality disorder. However, this pattern is not consistent across kinship groups. These and other results are discussed.

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CHAPTER I

BEHAVIOUR GENETICS AND PERSONALITY

"George Washington, Abraham Lincoln and Arthur Jensen: Are they compatible?" asked Crawford (1979). He argued that the conflict over the issue of heredity, the environment, and their contribution to human attributes, such as cognitive ability, is simply irrational. Crawford contends that this irrationality comes from the conflict between basic American social values and scientific findings. He generated a 2x2 truth table contrasting *beliefs* with *possible states of nature* and examined the possible consequences of each outcome. For example, IQ is largely genetic in origin *vs* IQ is largely environmental in origin. The conclusion he drew was that holding an environmental stance will not lead to Utopia in our grandchildren's day. Similarly, holding a purely hereditarian stance will not necessarily lead to social Darwinism (p. 664). Simply put, to insist that the environment entirely determines a trait ignores the contributions of genes to the structures that respond to the environment (Alexander, 1975), whilst organisms do extract information from situations that assists them in survival and reproduction (Shettlesworth, 1984).

Debates on the subject of "nature versus nurture" have come and gone, with current psychological wisdom embracing the so-called "interactionist" position. This position asserts that the development of behaviour involves a complex interaction of both genes and the environment (Wahlsten, 1990). Anastasi (1958) describes it as "... environmental and genetic threads...so tightly interwoven that they are indistinguishable...that there could be no behaviour without both environment and genes" (cited in Plomin, DeFries, & Loehlin, 1977, p.309). Oyama (1985), however, notes that although much "lip service" is paid to "interactionist" points-of-view, research and theory into this complex process is very thin. She writes,

> "How does it (interactionism) manage to be virtually universally adopted and lend itself to such radically different approaches. The suspicion is that it has become conceptually vacuous while acquiring the symbolic value of a membership badge, to be flashed upon entry into serious discussion: Yes, I belong to the company of reasonable people; now let's talk about the real stuff..." (pp. 4-5).

Oyama's statement conceivably best reflects the current approach to research in the field. Perhaps substantial research progress on the interaction of heredity and the environment has been unprofitable because inquiries of their singular contributions to behaviour are lacking in a number of crucial areas. This debate is actually far in advance of the research. A survey of contemporary behavioural genetics literature would likely show the majority of reports devoted to developing powerful methodologies to cleanly separate genetic and environmental influences. Furthermore, until recently, the bulk of the research reports has been largely descriptive in nature, consisting of reports of heritability coefficients. These are the indicators of *"how much"* of the variance of a trait in a sample is attributable to genetic and environmental factors.

It appears that a number of questions of *"how much"* have started to yield consistent results. For example, approximately 40% of the variance in personality or 50% of the variance in cognitive ability is attributable to additive genetic factors (see Plomin & Rende, 1991). Perhaps only in relatively under-researched areas, such as personality disorder (e.g., Seiver & Davis, 1991; Kendler & Hewitt, 1992; Livesley, Jang, Jackson, & Vernon, submitted), does such basic descriptive research continue. Furthermore, some effort must be spent examining the relationship between normal personality and personality disorder. For example, does normal personality and personality disorder have the same underlying etiologies? Are they affected by the same environmental factors? Very little behaviour genetic research exists on the interface of normal and abnormal personality. Indeed, perhaps once investigations take into account the origins of disorder will the operation of normal personality be better understood.

Once the questions of "*how much*" have been adequately addressed, it would be possible to begin posing questions of "*what*". For example, what forms of genetic or environmental influence affect personality function? When adequate answers to this question have been obtained, research on the interaction of genetic and environmental influences that produce complex behaviour can begin.

One of the aims of the present research is to conduct a comprehensive behaviour genetic analysis of normal personality and personality disorder. More specifically, normal personality and liability to personality disorder because the present investigation is based on a general population as opposed to a clinical sample. Examination of a sample from the general population is justified because the pattern of responses of general population subjects is similar to those of clinical samples (Livesely, Jackson, & Schroeder, 1992; Schroeder, Wormworth, & Livesley, 1992). Converging evidence indicates that differences between these two populations exist in the magnitude of their responses as opposed to differences in response pattern.

The data set to be analyzed in this investigation is unique in that it contains data on a broad range of measures that allow for a comprehensive analysis of a wide spectrum of behaviour and its possible precursors. This data set contains data on normal personality, liability to personality disorder, and a wide range of environmental measures, all drawn from a single sample with a twin structure. The research to be described herein is designed to take full advantage of this structure and variety of measures from the unique perspective of behavioural genetics. This paper will report a number of quantitative genetic analyses designed to estimate the influence of genes and the environment on each of the traits. This type of analysis not only extends to the measures of personality, but also to the environment itself. This idea does not appear so far-fetched when one considers that a person's personality, feelings, etc. may influence how the environment is perceived. Quantitative genetic analyses, however, are not limited to studying traits in isolation. These analyses can also be used to investigate the genetic and environmental factors that jointly affect a number of related traits. For example, this data set allows for the direct testing for the presence of a common genetic and/or environmental basis to measures of personality and liability to personality disorder.

Finally, the quantitative genetic analyses may identify a large environmental component on some or all of these measures. It then behooves one to try to identify what these environmental influences might be. A secondary aim of this investigation is to identify what aspects of the environment are related to personality and liability to personality disorder.

The conceptual framework of this study comes directly from quantitative genetic theory and the field of behavioural genetics. The discussions to follow will review and evaluate contemporary behaviour genetic research on personality. The conclusions drawn from this review will be used in the formation of comprehensive new research to be presented here.

Quantitative Genetic Theory

Quantitative genetic theory begins with a consideration of a single individual's phenotype (P; measurable trait). However, to be generalizable beyond a single person, quantitative genetic theory examines populations and studies the variance (sum of the squared deviations from the sample mean) of a character (V_P). The general form of the theory states that the variance of a phenotype is equal to the linear sum of the action of genes (genotype or V_G), and an environmental effect (V_E) due to all non-genetic causes:

$$V_P = V_G + V_E \quad (1)$$

V_G can further be partitioned into three effects. The first effect is the additive effect (V_A) of genes that represents effects attributable to segregating genes shared by family members whose effects sum linearly in their effect on the phenotype. This is the extent to which parents and children genetically resemble one another. These additive effects are the focus of most behaviour genetic studies. The second is genetic dominance (V_D) which occurs when another gene or dominant allele modulates gene expression at the corresponding locus of a homologous chromosome. The third effect is epistasis (V_I) which is when an allelle modulates gene expression at different loci. Plomin, DeFries, & McClearn (1990) or Falconer (1981) provide full details.

The environmental sources of variation (V_E) are partitioned into two general components referred to as the shared or common family environment (V_{E2}), and nonshared, random, or unique family environment (V_{E1}). Characteristics of the shared component of the environment distinguish the general environment of one family from another, and this component is expected to influence all children within a family to the same degree. Paternal income or socio-economic status is an example of such an influence. Nonshared environmental factors are unique to siblings and thus tend to make them different from one another (Rowe & Plomin, 1981). For example, when parents treat one offspring better than another. The nonshared environmental component also includes events that impinge on all family members but have differential effects on individual family members because of pre-existing differences such as age, or genetic predispositions (McCall, 1983). Examples include, family relocation, divorce, neighbours, or death of a relative. Also included in this component is random error variance, such as error of measurement.

There is no necessary relationship between the relative importance of shared and nonshared environments. That is, environmental factors that create differences within families can act independently of factors that cause differences between families. This can be true even when the same factor is involved. Plomin (1986) gives the example of parental love. 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. However, a child is likely to be painfully aware that parental affection toward him is less than that toward his sibling. Thus, nonshared experiences can be independent of shared experiences.

Two non-additive terms in the general model treat reciprocal G and E effects. Gene-environment interaction (GxE; in the analysis of variance sense) is present when a single environmental factor has a greater effect on some genotypes than on others. The second component is gene-environment correlation, when expressed in variance terms is 2Cov(GE). Conceptually, this refers to the differential exposure of genotypes to environments. Discussion of genotype-environment correlation centres around three main forms. They are commonly referred to as passive, reactive, and active (Plomin, DeFries, & Loehlin, 1977). A passive gene-environment correlation occurs when parents give their children both the genes and the environment that are favourable (or unfavourable) for the development of a trait. Reactive genotype-environment correlation occurs when people react differently to persons of different genotypes. Active genotype-environment correlation occurs when a child contributes to his/her own environment and actively seeks one related to his/her genetic propensities. Plomin, DeFries, & Loehlin (1977) discuss genotype-environment correlations and interactions in detail.

The variance of the phenotypic variations (V_P) as a function of the variance of the other components is as follows:

$$V_P = (V_A + V_D + V_I) + (V_{E2} + V_{B1}) + 2Cov(GE) + V_{GxE} \qquad (2)$$

A note on terminology is appropriate here. Plomin and Daniels (1987) point out that several labels are used to refer to the two general components of environmental variance. Shared environmental influences have been referred to as: "E2"; "between family"; and "common" environmental variance. Labels that have been used to refer to nonshared environmental influences include "E1"; "within-family"; "individual"; "unique"; and "specific" environmental variance. They found that the terms "within-" and "between-family" environments most often appear in the literature but that the terms "shared" and "nonshared" are the most accurate. The term "within-family" suggests factors that only occur within the confines of the family. However, "nonshared" influences are those that affect family members regardless of whether the influence comes from within or from without the family. Their suggestion will be followed here.

Behaviour Genetic Methods

Behaviour genetics is devoted to research on the inheritance of behaviour. As such, the field has concentrated on determining the relative proportion of the phenotypic variation in a sample of individuals attributable to genetic or environmental variation. This is possible by taking advantage of naturally occurring situations in nature - twins and adoptees, and their similarities and differences.

Intraclass Correlation

The basic data for behaviour genetic research is the extent to which relatives of different degrees of kinship resemble one another. Historically, and to some extent today, the intraclass correlation provided this information and deserves some comment. The intraclass correlation was preferred over the usual interclass correlations, such as Pearson's *r*, because Pearson's *r* assumes that each pair (X, Y) is independent of all other pairs. Such an assumption presumes that the person is the sampling unit, and as such, provides one and only one pair of scores. This is not the case when correlating siblings because each sibling provides one of the scores of a pair and the intraclass correlation makes no assumption of independence. Furthermore, the intraclass correlation is able to take into account all possible pairings of siblings within a family, useful when there are more than two children per family under study.

The intraclass correlation coefficient typically used in behaviour genetics research is computed from the between- and within-groups mean squares obtained from a simple one-way analysis of variance procedure. In this analysis of variance design, each sibling of a pair forms a group and the intraclass correlation (r_I) is computed by subtracting the within group mean square from the between groups mean square and dividing this quantity by the sum of the between and within group mean squares. However, it is interesting to note that if one randomly assigns one sibling to one arbitrary "class" and the other sibling to the other arbitrary "class" and then computes the usual interclass correlation, such as Pearson's *r*, the result is typically much the same (Plomin, DeFries, and McClearn, 1990, p. 258).

Uses of the Intraclass Correlation Coefficient in Behaviour Genetics

Intraclass correlation coefficients are used to compare unrelated adopted and biologically related siblings who were all reared together in the same home. The adoption design estimates the genetic influence by comparing the correlation for some trait between unrelated children reared together with that obtained between biological siblings reared together. If the adoptive siblings' correlation is lower than that obtained between biological siblings, this suggests that some of the trait variance is genetic rather than environmental in origin. In an adoptive home, environmental influences are equated both for adoptive and for biological siblings. Any differences in the magnitude of the correlations can only be attributable to the fact that biological siblings share approximately 50% of their genes on average and unrelated adoptive siblings do not share any genes.

The adoption method also provides a direct estimate of the environmental influences shared by family members (V_{E2}). The correlation between unrelated children in the same adoptive family directly estimates shared environmental influences because no genes can be implicated. Any similarities can only be due to the common environment of the adoptive home.

Twin data estimate genetic influence by comparing the correlations calculated between both identical or monozygotic (MZ) and fraternal or dizygotic (DZ) twins. If heredity does not contribute to the variance of the trait, then the two-fold greater genetic similarity of MZ twins should not make them more similar than DZ twins. If heredity is implicated, MZs will be more similar than DZ twins for the trait of interest and the correlation for MZ twins will exceed that of the DZs.

The family study examines related siblings in their biological home. The family study is not a powerful design because it confounds heredity and environment. Siblings may resemble one another because of similar parental treatments, inherited dispositions, or both. The family study is nonetheless useful in setting limits for shared and nonshared influences. Shared influences, whether genetic or environmental, cannot be greater than the correlations between siblings. To separate these influences however, one must use twin or adoption data.

Estimating Heritability

Sibling similarities are routinely used to estimate the proportions of variance attributable to each genetic and environmental component. The simplest and most illustrative of the logic comes from Falconer's (1981) method for twin data. Genetic variance (V_G) is estimated by h^2_B, better known as "broad sense heritability" as it includes variation from all genetic factors. Computation simply involves doubling the difference between the MZ correlation and the

DZ correlation. Variance attributable to shared environmental influences (V_{E2}), symbolized as c^2, is the difference between h^2_B and the MZ correlation. The MZ correlation contains both genetic and shared environmental variance, and by subtracting out h^2_B, one is left with an estimate of c^2. It follows that an estimate of nonshared environmental factors (e^2) is computed by $e^2 = 1.0 - h^2_B - c^2$.

Failure to meet a number of assumptions of the twin method can easily produce biased heritability and environmentality coefficients. First, if the environments of the MZ twins are more similar than the environments of the DZ twins, MZs would exhibit more similarity relative to DZs. This would cause an upward bias in h^2_B. Similarly, parents could create an environment that may systematically serve to increase the differences between DZ twins, again causing an over-estimate of h^2_B. Loehlin and Nichols (1976) referred to each of these as "assimilation" and "contrast" effects respectively. Recent research indicates that violations of these basic assumptions however, do not seriously bias estimates of h^2_B, c^2, and e^2 (see Plomin, DeFries, and McClearn, 1990). This research often involves specific measures of environmental factors, such as time spent together. Does the amount of time MZs spend together increase their similarity, or, is it because they are so similar that they spend a great deal of time together?

Recent evidence shows that similarity leads to contact (Lykken, McGue, Bouchard, & Tellegen, 1990). This is not to say that it is not possible that other aspects of the environment, or many environmental factors, each with a small effect, may sum together and violate the equal-environments assumption. The presence of non-random or assortative mating among the parents of twin pairs will also increase the amount of additive genetic variance shared by DZ but not MZ twins. This is because MZs share all their genes. A larger additive component for the DZ twins will increase their phenotypic correlations and reduce the difference between MZ and DZ twins which results in an underestimate of broad-sense heritability. This assumption has received little direct attention because very few studies have collected data on parents of twins.

Nonadditive Genetic Variance

An indication of nonadditive effects is a high MZ twin correlation and a DZ twin correlation no greater than that between unrelated persons. Plomin, Chuiper, & Loehlin (1990) suggest that nonadditive effects are present when the size of the MZ correlation is greater than twice the size of the DZ correlation for a trait, or when the broad-sense heritability estimate is greater than the correlation between MZ twins.

In a twin design, if nonadditive effects are present, they will bias the broad-sense heritability estimate. Unlike MZ twins who share all genes (additive and nonadditive), DZs and non-twin siblings share only a quarter of the genetic variance that is attributable to interactions between alleles at a locus (dominance) and very little genetic variance due to interactions among alleles at different loci (epistasis). Neither dominance nor epistasis contributes at all to the genetic resemblance between parents and offspring. Children inherit only one of two alleles at a given locus from each parent, and the inheritance of an allele at a particular locus is usually independent of the inheritance of another allele at another locus.

Often neglected in most discussions is a third form of polygenic interactions referred to as "emergenic traits" (Lykken, 1982). An emergenic trait is the result of a configuration of several or many independent or partly independent genes (p. 364) or the interaction of more than two genes at different loci. Lykken proposes the concept to explain those similarities in reared-apart identical twins that are not readily explained by the laws of polygenic transmission. For example, he writes, "One pair of our MZA (monozygotic twins reared apart) twins discovered that they were both in the habit of wearing seven rings. There is certainly no gene or set of genes devoted to 'ringedness'..." (p.364). The presence of such traits is indicated when the MZ correlation for a trait is very high whilst the DZ correlation is near zero.

Genotype-Environment Interaction

Currently, the detection of either genotype-environment correlation or interaction is extremely difficult. Jinks and Fulker (1970) proposed a test of the overall magnitude of genotype-environment interaction for a trait using the correlation of reared apart identical twin pair differences with their pair sums. The pair sums of identical twins reared apart contain variance attributable only to genetic factors and the pair differences contain only variance attributable to nonshared environmental differences. Although the correlation between pair sums and differences is a true test of genotype-environment interaction, a limitation is the scarcity of MZ twins reared apart. A further limitation is that it can only test for the overall magnitude of genotype-environment interaction effects and cannot specify the environmental influences responsible for the effects. More recently, Plomin, DeFries, & Loehlin (1977) proposed that genotype-environment interactions can be isolated with adoption data arranged in a factorial design.

Plomin (1986) applied this method to a number of sets of data and found little evidence for genotype-environment interaction effects on cognitive ability or on personality. This has been shown to be true for a variety of traits having a reasonably high heritability (Plomin & Daniels, 1987; Plomin, DeFries, & Fulker, 1988; Plomin, DeFries, & McClearn, 1990, Plomin, 1990). Contrary to some (e.g., Wahlsten, 1990), the detection of a significant genotype-environment interaction would not affect the heritability estimates. This is because main effects and interactions are independent - the main effects of G and E are not invalidated by the presence of GxE interaction (Plomin, 1990).

Gene-Environment Correlation

Scarr and McCartney (1983) proposed a general theory of development that uses the three categories of genotype-environment correlation described earlier. They suggest that passive genotype-environment effects predominate in infancy because much of the environment that reaches the child is provided by genetically related parents and siblings. As children grow toward adolescence, active genotype-environment correlation effects predominate where children seek and create environments conducive to the development of their genotypes. The reactions of people to children on the basis of their genetic propensity are an intermediate step in the process from infancy to childhood. Plomin (1986) writes that the value of their theory is that it uses behavioural genetic concepts to go beyond estimating components of variance to consider underlying developmental processes.

Unlike genotype-environment interaction, tests for genotype-environment correlations are few. Adoption data can provide a test for passive genotype-environment correlation. Plomin (1986) reasons that passive genotype-environment correlation does not occur for adopted children because their adoptive parents do not contribute both genes and environment to their development. This means that the phenotypic variance of adopted children has one less component than that of biological children. If passive positive genotype-environment correlation is important, the phenotypic variance of adopted children will be less than that of the biological children raised by their parents.

There has been only one test proposed for the overall contributions of reactive and active genotype-environment correlation. This also requires adoption data. Plomin, DeFries and Loehlin reason that the biological parents' phenotypes (IQ's for example) can be used as estimates of adoptive children's genotypes. These estimates are then correlated with aspects of the adopted children's environment (e.g., educational opportunities). They write that this method should work, but no appropriate data exist.

The presence of genotype environment correlations will bias heritability estimates if they contribute differentially to identical and fraternal twin pairs. Plomin, DeFries and Loehlin (1977) write that all three kinds of genotype-environment correlation may contribute more to the resemblance of MZ twins than of DZ twins. Identical twins may passively share more genes and environment in the sense that each twin provides a significant part of the co-twin's environment. Family members may react more similarly to their dispositions; and identical twins may actively seek more similar environments.

Model Fitting Techniques

A number of other factors may also affect heritability estimates calculated by Falconer's method. For example, even if all assumptions were met, the DZ twins could be negatively correlated and by subtraction would increase the difference. For example, Livesley *et al.* (submitted) found a negative DZ correlation (-.01) on a measure of intimacy problems whereas the MZ correlation was positive (.40). By Falconer's method, $h^2 = 2(.40 - -.01) = .82$, $c^2 = (.40 - .82)$

= -.42. Since an estimate cannot be negative, c^2 must be set to 0.0, leaving e^2 estimated at .18. Model-fitting analysis, which forces estimates to be sensible within a quantitative genetic model produced estimates of h^2 = .34, c^2 = .00, and e^2 = .66. Even with this small negative DZ correlation a noticeable bias in the heritability estimate is obtained. The estimates can become even more nonsensical when the magnitude of the negative correlation increases.

McGue and Bouchard (1984) demonstrated that age and sex can also bias heritability estimates to the extent that they are related to the trait under study. A further difficulty with this method of estimation is that it has low reliability or power with samples of less than 200 pairs - 100 of each type of twin (Plomin, 1986). However, refined and more powerful estimates are possible with a model-fitting approach that utilizes structural equations. They are superior because each estimate and its underlying assumptions are explicitly represented. Furthermore, additive or nonadditive genetic effects can be modelled. Nevertheless, regardless of the derivational method used to obtain the heritability and environmentality estimates, they must all be interpreted with the same general caveat. This is that they are only estimates and can change, especially if the trait in question is developmental in nature.

Replication on independent samples is always necessary.

Neale, Heath, Hewitt, Eaves, & Fulker (1989) and Heath, Neale, Hewitt, Eaves, & Fulker (1989) fully discuss model fitting approaches. The structural model used most frequently to estimate heritability is known as the A,C,E model. This model evaluates the effects of additive genetic variance (A) and thus only narrow-sense heritability; environmental variance attributable to experiences common to twins within each pair (C); and environmental variance due to factors not shared by co-twins (E). This model is presented in Figure 1.1. A further advantage of this technique is that it allows the fitting of three additional models that systematically test the relative importance of each of the three components. The first model removes all additive genetic influences to determine if a purely environmental model (C,E only) can account for the data. Similarly, the second model predicts no common environmental effects (A,E only). The third model predicts no familial resemblance (E only). Goodness-of-fit of a model is determined by χ^2. A nonsignificant χ^2 means that the model and the data do not differ significantly. A number of other

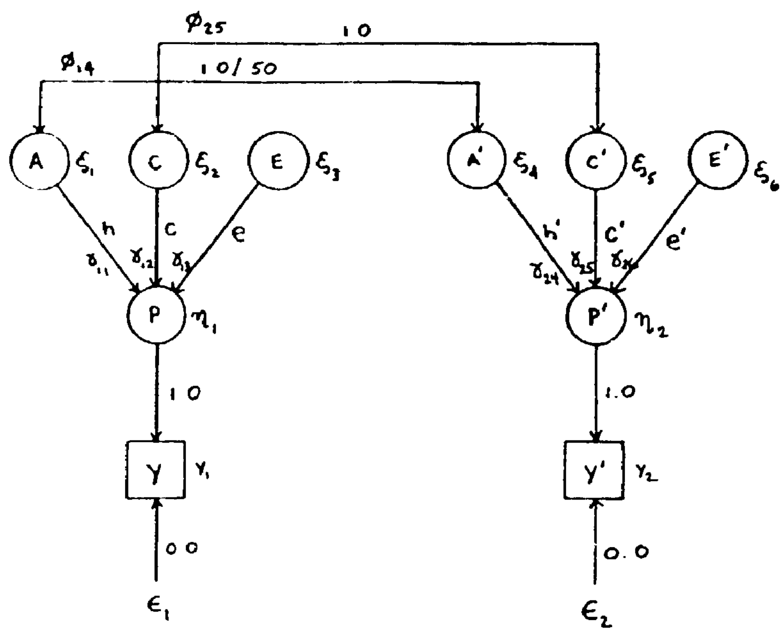


Figure 1.1. *Univariate Genetic Model.* P, A, C and E denote the phenotype, additive genetic variation, shared environmental variation, and nonshared environmental variation of the first twin; P′, A′, C′, and E′ denote the corresponding variables for the second twin; Y and Y′ denote observations on the first and second twins. Parameters h, c, e are the maximum likelihood parameter estimates which are squared to form h^2, c^2, and e^2 estimates. Standard LISREL notation is also included on the figure for each latent and observed variable and parameters.

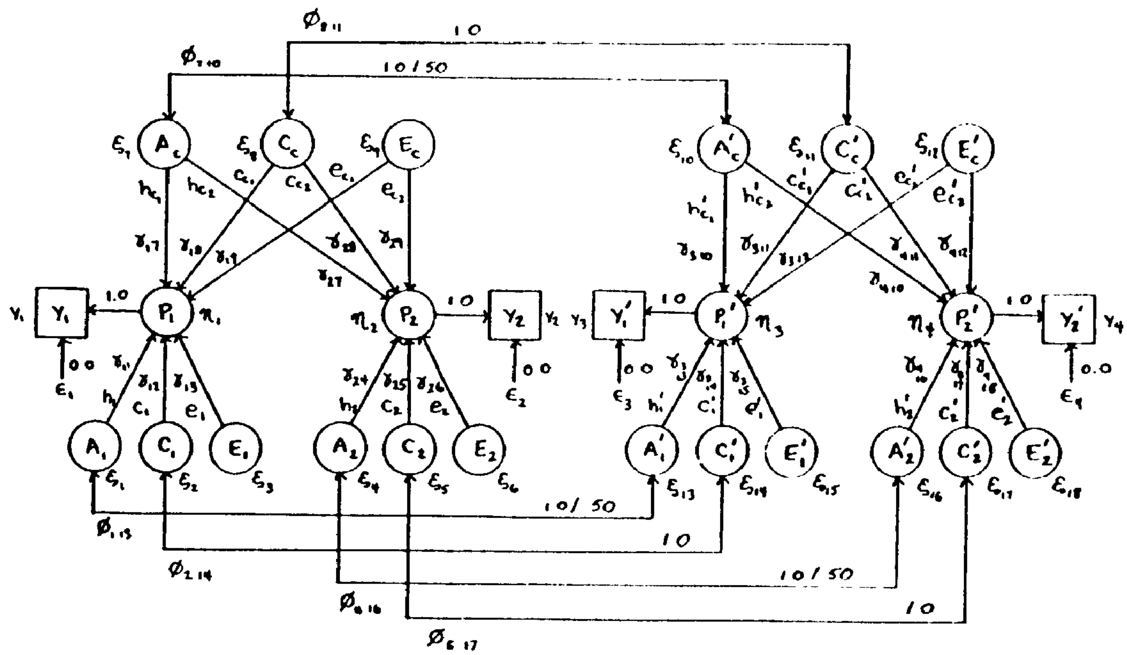
goodness-of-fit criteria such as Aikaike's Information Criterion (1970, 1981) are also applicable. This particular test yields a superior assessment of fit in models that have a small number of parameters (Bollen, 1989).

Multivariate models involving two or more variables per twin are also testable. Of particular interest are the common factor models. These models test whether common genetic and environmental factors underlie some or all or traits under study. These models also test for genetic and environmental effects wholly unique to each variable. Multivariate genetic analyses are a generalization of factor analysis, in which phenotypic correlations or covariances between variables and cross-variable covariances between kinship pairs are used to estimate loadings on separate genetic, shared environmental and nonshared environmental factors. The results of the narrow-sense heritability analyses should not be confused with the results of the common factor model fitting. Narrow-sense estimates yield the proportions of variance attributable to additive, shared, and nonshared sources uniquely associated with the variable alone. Common factor model fitting analyses test for those additive, shared, and nonshared factors that are <u>only in common</u> to a set of related dimensions, and this may constitute only a small proportion of the total genetic variability.

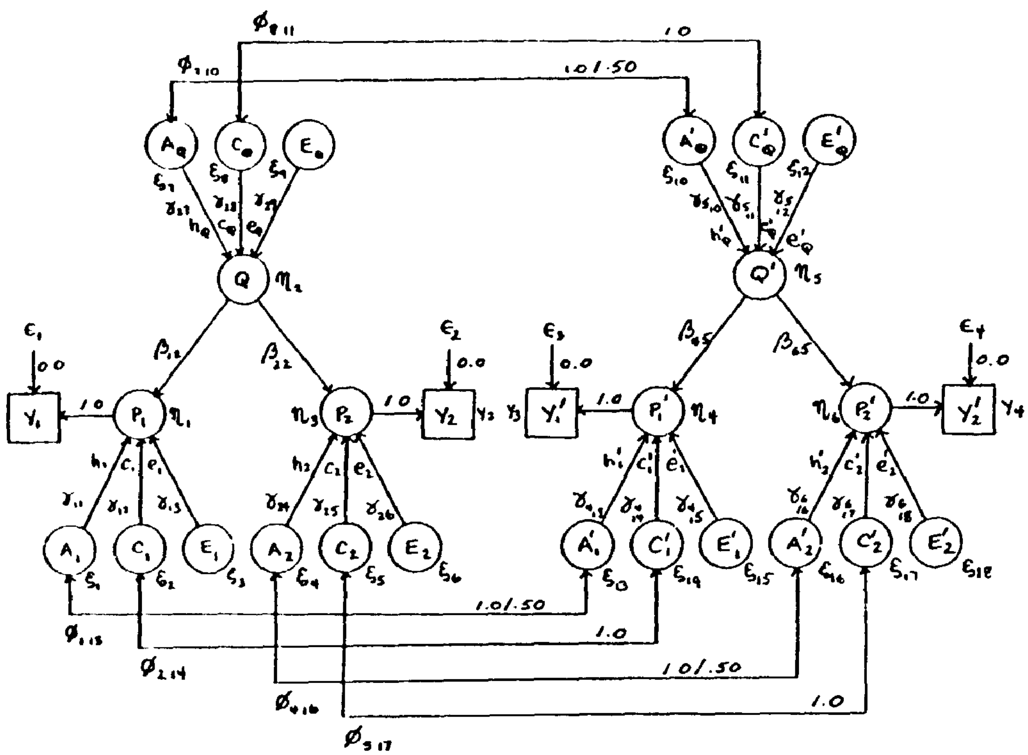
Multivariate models used in behaviour genetic research typically come in two general forms. There are "biometric common factor models" and "psychometric common factor models". Psychometric common factor models differ from the biometric models in that they include a common pathway or intervening summary variable between a phenotype and genetic and environmental causes. For example, in the case of cognitive ability, genetic and environmental effects on observed IQ test scores may be mediated through a general intelligence factor such as "g" may factor. In contrast, a biometric model would test for common genetic and environmental influences directly affecting each test score. The general form of each type of model is presented in Figures 1.2 and 1.3 respectively. These models are fully discussed by Martin & Eaves (1977) and McArdle & Goldsmith (1990).

Studies of Normal Personality

There are a plethora of behavioural genetic studies of personality published to date; to review them all would make for a very long review indeed. Despite the number, they are surprisingly homogenous in a number of important ways. First, they are primarily composed of studies of young adults. Second, they are almost all based on self-report measures of personality. Very few have used direct



<u>Figure 1.2.</u> General Multivariate Biometric Model. A_c, C_c, E_c denote the genetic variation, shared environmental variation, and nonshared environmental variation common to the phenotypes ($P_1, \ldots P_n$). The primes (′) denote the corresponding variables for the second twin. $Y_1, \ldots$ and Y_n denote observations on the first and second twins. Parameters h_{c1}, c_{c1}, $e_{c1}, \ldots h_{cn}$, c_{cn}, e_{cn} are the maximum likelihood parameter estimates which are used to form h^2_{c1}, c^2_{c1}, $e^2_{c1}, \ldots h^2_{cn}$, c^2_{cn}, e^2_{cn} estimates. A_1, C_1, $E_1, \ldots A_1$, C_1, E_1 denote the genetic variation, shared environmental variation, and nonshared environmental variation unique to the phenotypes ($P_1, \ldots P_n$). Parameters h_1, c_1, $e_1, \ldots h_n$, c_n, e_n are the maximum likelihood parameter estimates which are used to form h^2_1, c^2_1, $e^2_1, \ldots h^2_n$, c^2_n, e^2_n estimates. Standard LISREL notation is also included on the figure for each latent and observed variable and parameters.



<u>Figure 1.3.</u> *Psychometric Multivariate Genetic Model.* A_Q, C_Q, E_Q denote the genetic variation, shared environmental variation, and nonshared environmental variation of the intervening variable (Q) between the phenotypes (P_1,...P_n). Parameters h_Q, c_Q, e_Q are the maximum likelihood parameter estimates of the above. A_1, C_1, E_1,...A_1, C_1, E_1 denote the genetic variation, shared environmental variation, and nonshared environmental variation unique to the phenotypes (P_1,...P_n) with the maximum likelihood parameter estimates denoted as h_1, c_1, e_1,...h_n, c_n, e_n. The primes (′) denote the corresponding variables for the second twin. Standard LISREL notation is also included on the figure for each latent and observed variable and parameters.

observation or any other methodology (Plomin, 1981). Third, and perhaps most striking, all studies appear to converge to the same result. Although heredity accounts for approximately 30% to 50% of the explained variance, the environment accounts for about as much. Furthermore, nonshared environmental factors account for approximately 80% of the environmental variance in personality. This finding is consistent over different designs (twin or adoption), different measures of personality, or different methods to calculate heritability (Falconer's or model-fitting). The present review will look at only a small number of the available studies to show that regardless of the design, the measures, or the estimation method employed, they all converge on the same general conclusion.

Four studies in particular are notable for their size and differences in the national character of their samples. The results of these studies are presented in Table 1.1. On average, MZ correlations are about .50, and DZ correlations are about .30. Application of Falconer's formula yields an average heritability of 40%. More surprisingly, this leaves the proportion due to shared environmental variance at 10% and approximately 50% to nonshared environment. It is also interesting to note that nonadditive effects may underlie Neuroticism and Extraversion. For these dimensions the MZ correlations are

Table 1.1

Intraclass Correlations for Neuroticism and Extraversion from Four Large Twin Studies

	Neuroticism				Extraversion			
Sample	MZ-F	MZ-M	DZ-F	DZ-M	MZ-F	MZ-M	DZ-F	DZ-M
U.S. adolescents	.48	.58	.23	.26	.62	.57	.28	.20
Swedish Adults	.54	.46	.25	.21	.54	.47	.21	.20
Australian Adults	.52	.46	.26	.18	.53	.50	.19	.13
Finnish Adults	.43	.33	.18	.12	.49	.46	.14	.15
Numbers of Pairs:								
United States	284	197	190	122	284	197	190	122
Sweden	2720	2279	4143	3670	2713	2274	4130	3660
Australia	1233	566	751	351	1233	556	751	351
Finland	1293	1027	2520	2304	1293	1027	2520	2304

Note: MZ = monozygotic, DZ = Dizygotic; -F = females, -M = males. Studies: United States, Loehlin & Nichols (1976); Sweden, Floderus-Myhred, Pedersen, & Rasmuson (1990); Australia, Martin & Jardine (1986); Finland, Rose, Koskenuvuo, Kaprio, Sarna, & Langinvainio (1988). The table is from "Environmental and Genetic Contributions to Behavioral Development" by J.C. Loehlin, 1989, *American Psychologist, 44*, 1285-1292.

more than double the DZ correlations in all the samples.

Smaller, but still powerful studies using the twins reared apart methodology, employing different personality measures and model-fitting techniques have found similar results. Tellegen, Lykken, Bouchard, Wilcox, Segal, and Rich (1988) administered the Multidimensional Personality Questionnaire (MPQ) to 217 MZ and 114 DZ reared together adult twin pairs and 44 MZ and 27 DZ reared apart adult twin pairs. The heritability estimates obtained with model-fitting techniques ranged from .39 to .58, with a small and negligible shared environmental component and correspondingly significant nonshared component for all but 2 of 14 personality scales. Bouchard, Lykken, McGue, Segal, and Tellegen (1990) and Bouchard and McGue (1990) studied over 100 pairs of MZ and DZ separated and reared apart twins. On a number of diverse personality measures (MPQ and California Personality Inventory: CPI), they found genetic effects to account for approximately half of the variance, a result consistent with those noted above.

The majority of twin studies have examined young adult twins reared together. Pedersen, Plomin, McClearn, and Friberg (1988) studied a sample of 99 MZ and 229 DZ twins reared apart and a matched set of 160 MZ and 212 DZ twins reared together who were at least 50 years of age. The relative importance of genetic and environmental factors for Neuroticism, Extraversion, Impulsivity, and Monotony Avoidance was examined. A number of model-fitting analyses were performed to test the effects of selective placement of the reared apart twins and to test for nonadditive genetic effects. The results showed that significant genetic variance for personality measures exists later in life. The broad-sense heritability of Extraversion was 41%, of which all was attributable to nonadditive genetic effects. Additive genetic variance accounted for all the genetic variance in Neuroticism (31%) and Monotony Avoidance (23%). Total genetic effects on Impulsivity were reported to be 45%, with .04% of the total being directly attributable to additive effects. As is typical with studies of personality, shared environmental effects account for very little of the total variance (range 5% to 10%) with nonshared environmental factors accounting for most of the total variance (52% to 72%). Selective placement appears to affect Neuroticism, accounting for 16% of the total variance. The heritability estimates reported are somewhat lower than those obtained on studies of younger twins. This implies that the role of genetic factors later in life is still significant, but becomes less important. The results also confirm the importance of nonadditive genetic factors for Extraversion and Impulsivity. Evidence for nonadditive effects for Extraversion has been reported in a number of other studies (Eaves & Young, 1981; Martin & Jardine, 1986: Eysenck, 1990). The presence of nonadditive genetic factors in some personality dimensions and not others may serve as an important clue into the etiology of different personality dimensions. It is really not enough to say how much of a trait is heritable, but one must also determine the nature of the heritable component.

Yet another conceptualization of personality is the "Big Five" model of personality. The five factors are Neuroticism (N), Extraversion (E), Openness (O), Agreeableness (A), and Conscientiousness (C). Jang, Livesley, and Vernon (in preparation) estimated the narrow-sense heritabilities of these five dimensions and fitted biometric common factor models to determine the extent to which a complex of common genetic and/or environmental factors may underlie all, or a subset of the five dimensions. A sample of young adults from the general population composed of 91 monozygotic (MZ) twin pairs and 84 pairs of dizygotic (DZ) twins completed the NEO Personality Inventory (Costa & McCrae, 1985), a measure of the so-called "Big Five". Heritability estimates are presented in Table 1.2. Statistically significant additive genetic contributions were detected for Neuroticism (.51) and Conscientiousness (.63). Genetic effects were present but not statistically significant for Openness (.45) and

Table 1.2

Narrow-sense Heritability and Environmentality Estimates of the NEO Personality Inventory Scales

Dimension	h^2_N	c^2	e^2
Neuroticism	.51	.00	.49
Extraversion	.19	.30	.50
Openness	.44	.09	.47
Agreeableness	.00	.45	.55
Conscientiousness	.63	.00	.37

Extraversion (.19). Agreeableness appears to be completely determined by the environment ($c^2 = .45$, $e^2 = .55$).

The narrow-sense heritability estimates for Neuroticism, Openness, and Conscientiousness are not unlike those typically found for personality variables. Extraversion and Agreeableness however, show little to no additive genetic influence. The low additive genetic component is not surprising with Extraversion. As noted before, the genetic component for this trait appears to be largely nonadditive in nature and attributable to genetic dominance (Pedersen, Plomin, McClearn, & Friberg, 1988; Eysenck, 1990). The zero heritability found with Agreeableness is not completely unexpected as Plomin *et al.* (1990) report a heritability for Agreeableness to be quite low, at approximately .18 in a sample of twins reared apart.

Taking the analyses a step further, biometric common factor models were fitted to the five dimensions. Satisfactory fits were obtained in all models except when all five dimensions were analyzed simultaneously. Close examination of the models showed that Agreeableness and Conscientiousness shared no common genetic or environmental etiology. The best overall fit to the data was obtained when only Neuroticism and Extraversion, the two "super factors" were analyzed together. A very clear genetic correlation exists between these two variables. Almost 96% of the common genetic variance in Neuroticism comes from the same source as Extraversion, of which about 60% of its common variance is shared genetic variance with Neuroticism. The remainder of the common variance is environmental in nature. Very little of the environmental variance shared by Neuroticism and Extraversion is attributable to shared environmental influences. Although 34.6% of the shared variance in Extraversion is attributable to nonshared influences, only 3.7% of Neuroticism common variance is drawn from the same source.

Detailed examination of these common effects shows a positive effect on Neuroticism with a concomitant negative effect on Extraversion. This finding is consistent with any substantive interpretation of the relationship between Neuroticism and Extraversion. It is expected that as neurotic tendencies increase, the tendency toward extraversion would decrease. A complete report of the common and unique factor heritability estimates and their valances is presented in Table 1.3.

One area of research receiving greater attention is personality change. Plomin and Nesselroade (1990) reviewed the available developmental behaviour genetic personality

Table 1.3

Heritability and Environmentality Estimates of Common and Unique Sources of Variation

	Common			Unique		
Scale	h^2_N	c^2	e^2	h^2_N	c^2	e^2
Neuroticism	.95 (+)	.01 (+)	.04 (-)	.26	.00	.74
Extraversion	.59 (-)	.06 (-)	.35 (-)	.03	.40	.57

Note: + indicates a positive relationship between the personality trait and additive genetic, shared environmental, and nonshared environmental influences; - indicates a negative relationship between the personality trait and additive genetic, shared environmental, and nonshared environmental influences.

research and concluded that genetic involvement is great during childhood but becomes slight in adulthood. McCartney, Harris, and Bernieri (1990) came to much the same conclusion when they conducted a meta-analysis of 103 developmental twin studies of cognitive ability and personality. Their meta-analysis clearly shows strong negative correlations between the heritability of personality variables and age. Clearly, the negative correlations increase as twins get older, indicating that over time, they become more dissimilar. These are shown in Table 1.4.

These very short reviews of some behavioural genetic personality studies show that heritability coefficients for personality are moderate, typically ranging from 30% to 50%.Shared environmental effects usually comprise no more than 10% of the explained variance with nonshared environmental influences (and error) accounting for the remainder. Furthermore, there is evidence that the heritability of personality changes over time. Genetic influences are greatest in childhood and dissipate over time.

Studies of Liability to Personality Disorder

Investigations of the genetic contribution to normal

Table 1.4

Correlations between Intraclass R's and Age of Twins on Personality Variables

Variable	# of studies	MZ	DZ	Age Range
Activity-Impulsivity	14	-.48	-.33	1 - 50 yrs
Aggression	8	-.09	-.06	7 - 47
Anxiety	5	-.34	-.49	7 - 30
Dominance	5	.67	.07	7 - 50
Emotionality	8	-.11	.30	1 - 50
Masculinity-Femininity	7	-.81	-.74	7 - 50
Sociability	20	-.24	.26	3 - 50
Task Orientation	5	-.69	-.89	1 - 50

Note: Table from McCartney, Harris, & Benieri (1990), p. 223.

personality traits consistently report heritabilities in the 0.40 to 0.60 range with MZ correlations averaging about 0.50 across different traits and DZ correlations averaging about 0.30. In contrast to the extensive investigation of normal personality, research on the genetics of personality disorders is sparse. Familial aggregation has been demonstrated for some disorders, especially borderline and schizotypal personality disorders (Silverman, Pinkham, Horvath, Coccoro, Klar, Schear, Apter, Davidson, Mohs, & Seiver, 1991; Seiver & Davis, 1991; Baron, Gruen, Asnis, & Kane, 1983; Schulz, Schilz, Hasmer, Resnick, Freidel, & Goldberg, 1985; Links, Steiner, Mitton, 1989; Huxley, Goldberg, MacGuire, & Kincey, 1979). Although these studies point to a genetic component, the family study design confounds genetic and environmental factors, and only provides limited information on the magnitude of genetic and environmental influences. Twin or adoption designs are required to separate and quantify genetic and environmental effects. Few studies have reported on the heritability of either the categories or specific traits of personality disorder. Predisposition to schizophrenia, or schizotypy has received some behavioural genetic attention. Kendler and Hewitt (1992) report heritabilities centering around .45 or greater.

Behaviour genetic studies that have surveyed a broad range of personality disorder are few in number. What has been done has centred on the Minnesota Multiphasic Personality Inventory (MMPI). The most recent study is by Rose (1988). He computed the heritability coefficients of nine factor scales identified from a factor analysis of the MMPI items administered to a non-clinical sample. A sample of 228 MZ and 182 same-sex DZ twin pairs completed the nine factor scales. His findings are presented in Table 1.5. The presence of substantial genetic influence was detected on Neuroticism (.38), Psychoticism (.58), Extraversion (.36), Somatic Complaints (.44), Inadequacy (.64), and Cynicism (.34). On the other hand, the Religious Orthodoxy, Masculinity *vs* Femininity, and Intellectual Interests scales show little genetic influence (≤ .16). Shared environmental effects are often small on most personality traits, but the Masculinity *vs* Femininity and Extraversion factor scales showed significant shared environmental effects. Finding such a large shared component on Extraversion is puzzling as previous studies showed it to be negligible, with nonshared environmental influences being responsible for the environmental variance. Rose does not offer any explanation of this result. One reason may be that the MMPI factor scale may be somewhat different in content to Extraversion as measured by Eysenck and Eysenck's (1975) EPQ scales.

Table 1.5

Genetic and Environmental Sources of Variance Computed with Falconer's Method in the Nine Factor Dimensions of the MMPI

Scale	h^2_B	c^2	e^2
Neuroticism	.38	.03	.11
Psychoticism	.58	.12	.30
Masculinity *vs* Femininity	.12	.64	.24
Extraversion	.36	.24	.40
Religious Orthodoxy	.10	.61	.29
Somatic Complaints	.44	.00	.56
Inadequacy	.64	-.10	.46
Cynicism	.34	.17	.49
Intellectual Interests	.16	.40	.44

Note: Table adapted from Rose (1988), p. 306.

Table 1.6

Twin Studies of the MMPI

Scale	Twin Correlations	
	MZ	DZ
Social Introversion	.45	.12
Depression	.44	.14
Psychasthenia	.41	.11
Psychopathic Deviate	.48	.27
Schizophrenia	.44	.24
Paranoia	.27	.08
Hysteria	.37	.23
Hypochondriasis	.41	.28
Hypomania	.32	.18
Masculinity-Femininity	.41	.35

Note: Table from Vandenberg (1967).

Vandenberg (1967) presented twin correlations from 120 MZ and 132 DZ pairs for the ten original MMPI scales. He summarized two studies by Gottesman (1963, 1965) and one by Reznikoff and Honeyman (1967). These are presented in Table 1.6. These correlations indicate substantial genetic influence on the MMPI scales. Of particular interest, the heritability coefficients appear to be somewhat higher than those typical of normal personality. Furthermore, many of the MZ correlations are more than twice the size of the DZ correlations, indicating that nonadditive genetic effects are present in many of the measures of psychopathology.

Livesley, Jang, Jackson, and Vernon (submitted) assessed the basic dimensions of personality disorder in a general population sample of 175 twin pairs (90 MZ and 85 DZ) using the Dimensional Assessment of Personality Pathology, a questionnaire developed to assess eighteen dimensions of personality disorder. The questionnaire was developed on the basis of factor analytic studies that identified a stable structure underlying personality disorders in clinical and non-clinical samples (Livesley, Jackson, & Schroeder, 1989, 1992). Model fitting methods were used to estimate heritability coefficients. These are presented in Table 1.7. Estimates of heritability range from zero for Conduct Problems to .62 for Narcissism. The best-fitting model was one that specified additive genetic

Table 1.7.

Heritability Estimates of Genetic and Environmental Influence on Personality Disorder as Measured by the DAPP-DQ

Dimension	h^2_N	c^2	e^2
Affective Lability	.459	.000	.545
Anxiousness	.486	.057	.457
Callousness	.584	.018	.398
Cognitive Distortion	.411	.144	.445
Compulsivity	.389	.031	.580
Conduct Problems	.000	.526	.474
Identity Problems	.583	.000	.420
Insecure Attachment	.355	.128	.517
Intimacy Problems	.343	.000	.660
Narcissism	.616	.000	.399
Oppositionality	.552	.000	.448
Rejection	.447	.052	.500
Restricted Expression	.480	.043	.477
Self Harm	.278	.000	.722
Social Avoidance	.554	.000	.448
Stimulus Seeking	.499	.085	.415
Submissiveness	.253	.282	.465
Suspiciousness	.486	.000	.515

and unique environmental effects. These results are similar to those obtained for normal personality dimensions. Additive genetic factors are shown to be central in most, but not all dimensions of personality disorder. Furthermore, examination of the twin correlations shows that nonadditive effects may be present in most of the DAPP dimensions. Nonshared environmental factors were also shown to have a substantial effect on every dimension and the influence of common environmental factors is small for all dimensions except Conduct Problems.

Conclusions

The attention of behaviour geneticists has typically focused on heredity and the development of methodology to separate it from other effects. Application of this methodology to investigations of personality and personality disorder shows that although genetic influences are ubiquitous for most personality traits, the environment, particularly nonshared environmental influences, contributes approximately as much to personality as do genetic influences. Nonadditive genetic effects also appear to be present on most personality traits, and their presence is indicated on measures of personality disorder.

This short review indicates a number of areas where more attention must be paid. First, the magnitude of possible nonadditive effects must be clarified for normal personality and personality disorder. Clearly, these effects are indicated, but few studies have estimated their magnitude. Second, continuing descriptive research must be conducted on a spectrum of personality disorders. Currently the research on personality disorder is sparse and evidence as to the magnitude of genetic and environmental effects is limited. Once this has been accomplished, the next step will be to look for relationships between variables from the two content domains. Finally, the identification of nonshared environmental factors should be attempted because these influences play a significant role in normal personality and personality disorder as well.

CHAPTER II

THE NONSHARED ENVIRONMENT

The previous chapter ended with a call for research in four areas. These are: 1) the magnitude of possible nonadditive effects must be clarified for normal personality and personality disorder; 2) continuing descriptive quantitative genetic research on a spectrum of personality disorders; 3) examination of relationships between content areas, such as normal and abnormal; and 4) the identification of nonshared environmental factors related to personality and personality disorder. The first three calls are relatively straightforward to fulfil. This is because these areas simply require changing content areas or minor alterations to standard quantitative genetic analysis, which is blessed with a well developed theory and methods for study. The fourth and final call is somewhat harder to accomplish. There exists little theory on nonshared environments and the methods used to measure and study the phenomenon are presently embryonic.

To enable the present study to initiate a tenable study of nonshared environmental influences, a significant amount of time must be spent reviewing the key literature that is available. This will provide a starting point for how a new study should proceed, and forewarn of any potential problems. The first place to start is with a theoretical framework to define what comprises the nonshared environment.

Contents of the Nonshared Environment

Where do environments differ? Rowe and Plomin (1981) theorized that there are six general classes of nonshared environmental influence.

The first is simple *measurement error* that may limit the size of sibling intraclass correlations. It is possible to use the size of the reliability coefficients of different personality traits to estimate the importance of error. Age is also included as a source of measurement error if the traits under study change developmentally. This is not a difficulty for the study of twins. Studies of nontwin siblings, however, should adjust scale scores for age, or make longitudinal observations to allow comparisons at the same age.

The second general class discussed are *accidental factors*. This class includes any physical and emotional factors that may affect one sibling but not the other. The example is given of a mother who contracts rubella during the pregnancy of one child but not during her other pregnancies. This class includes physical illnesses, pre- and postnatal traumas, as well as early parent-child separations that may affect one sibling but not the other.

Interactions between siblings can lead to sibling differences because they may treat one another differentially. For example, one can be competitive and the other supportive. Siblings could also assume complementary roles that serve to reinforce their differences. For example, one sibling can be dominant and the other submissive. Rowe and Plomin warn, however, that it is plausible that reciprocal sibling interaction can serve to emphasize similarities rather than differences between siblings. It is also possible that the mutuality of sibling interaction has no effect on the behavioural outcome of siblings.

The fourth general class is *family structure*, which encompasses birth order and birth spacing variables. These variables automatically contrast siblings with one another and completely rule out genetic confounds.

The fifth class is *differential parental treatment.* Rowe and Plomin give the example of the child that gets labelled the "musically gifted one". He or she may be encouraged in this regard at the expense of the other siblings. Differential parental treatment may also appear as systematic differences in parental punishment, attention, and in extreme cases, in the provision of resources such as food or care (as discussed in Trivers, 1972, 1985).

The final category discussed is the possible influence of *extra-familial networks*. These include peers, relatives, friends of a family, teachers, and other individuals who may cause siblings to differ. Peer groups are an example of this type of influence because siblings typically do not share the same peer group, especially if there is a large age gap.

McCall (1983) groups nonshared sources of influence into two general conceptual classes. The first class includes those factors that exert a continuous influence on one child over another within the same family. These are referred to as *continuous nonshared within-family environmental factors*. He illustrates this concept with the example of what it may be like to be a first-born male. This may be associated with patterns of parental favouritism for intellectual pursuits, or the child may look to parents, rather than peers, as stronger role models for achievement. By definition, these continuous factors should contribute a constant amount to mental performance over time.

McCall's second class involves those influences that occur more frequently at one age than at another. These influences will have no effect before a certain point in time, but may exert a temporary or permanent influence from then on. McCall calls these *discontinuous nonshared within-family environmental factors*. These factors would not be present througnout a child's life but may influence various traits when they occur, and for varying periods of time thereafter. Examples might include moving into a new school district, or the development of parent-child alienation in adolescence.

The Nature of Nonshared Environment

The next step in understanding the nonshared environment came when a person's perceptions of the environment became the focus of research. For example, consider a parent who does not talk much to his or her children. The parent may be seen as either distant but loving, or as hostile (from Rowe, 1983), and presumably it is the child's perception that will exert the greatest influence in his/her development.

Plomin and Bergeman (1990) wrote that the problem with the typical psychological approach to the environment is that it comes from the traditional stimulus-response model, where the environment is independent of the organism. This conception of the environment allows no role for heredity because the environment is completely exogenous. However, they make the case that self-report measures of the environment blur the distinction between the environment and the organism. Self-perceptions filter through feelings, personality, and cognitions of the individual and become incorporated into the measure of the environment (p. 373).

Rowe's (1981) study was the first to directly examine if there were any genetic effects on environmental measures. He used the classic twin method, a major assumption of which is that home environments of MZ twins are not systematically different from that of DZ twins. Rowe reasoned that because MZ twins share all of their genes and DZ twins only 50% on average, and if the common family environments are the same, then MZ and DZ correlations should be identical and significantly greater than zero if heredity does not affect perceptions.

Rowe's (1981) sample consisted of 46 MZ and 43 DZ same-sex twin pairs in Grades 8 to 12. The mean age was 17.3 years and the sample was disproportionately female (61.1%). Shaefer's Children's Reports of Parental Behavior Inventory was administered as a measure of the twins' parent's behaviour toward them. Factor analyses of this questionnaire, Rowe reports, have consistently revealed three factors: Acceptance and Rejection (A-R), Psychological Control versus Psychological Autonomy (PC-PA), and Firm versus Lax Control (F-LC). The intraclass correlations for the perceived parenting dimensions are presented in Table 2.1.

Rowe reports that all intraclass correlations above .30 were significant at $p \leq .05$. In addition, he detected no significant differences between MZ and DZ intraclass correlations except for maternal and paternal A-R. Results of this study suggest little genetic influence in children's perceptions on the F-LC and PC-PA parenting dimensions but a significant genetic influence on a child's perception of maternal and paternal acceptance-rejection. These results suggest that some children's perceptions of their parent's behaviour toward them are not always a true reflection of what these behaviours might actually might be.

Rowe (1983) replicated his findings on adolescents with the same methods but included non-twin opposite-sex sibling pairs to test for any sex differences. Rowe administered the Family Environment Scale (FES; Moos and Moos, 1974) to a sample consisting of 59 MZ twin pairs, 31 DZ twin pairs (of which 11 were opposite-sex pairs), and 52 non-twin same-sex and 66 non-twin opposite-sex sibling pairs. Factor analysis

Table 2.1

Intraclass Correlations for Perceived Parenting Dimensions

Dimensions	MZ	DZ
Perceptions of Father		
A-R	.74	.21*
PC-PA	.43	.46
F-LC	.43	.45
Perceptions of Mother		
A-R	.54	.17*
PC-PA	.44	.47
F-LC	.55	.46

Note: * MZ and DZ intraclass correlations are significantly different at $p \leq .05$; Table adapted from Rowe, 1981, p. 205.

of the FES scores yielded two factors. The first factor was named Acceptance-Rejection (A-R) as it appears to reflect quality of parent-child interactions (e.g., parents and children do not fight; can express positive emotions; and share in activities). The second factor was labelled Restrictiveness-Permissiveness (R-P) on which a high score would indicate strong parental pressure to conform to family norms in the areas of achievement, religion, and family maintenance behaviours. Table 2.2 presents the intraclass correlations on these factors. The MZ intraclass correlation was significantly larger than the DZ intraclass correlation on the A-R factor (.63 *vs* .21, respectively). MZ and DZ twin correlations were essentially equal on the R-P dimension (.44 *vs* .54). Same-sex and opposite-sex siblings agree on both the A-R and R-P dimensions ($r_{same-sex}$ = .45 *vs* $r_{opposite-sex}$ = .46; $r_{same-sex}$ =.62 *vs* $r_{opposite-sex}$ = .56, respectively). Considered as a whole, these results agree with those found in Rowe's (1981) study. There is a significantly greater MZ than DZ twin correlation for parental acceptance, but nearly equal correlations for parental control. Sex differences also do not appear to affect perceptions on any dimension as shown by the opposite-sex and same-sex sibling intraclass correlations which were not significantly different from one another. Rowe's findings suggest restricting research to sibling perceptions because they may be genetically mediated. A

Table 2.2

Sibling Intraclass Correlations of FES Factors

Dimension	MZ	DZ	Same-sex Siblings	Opposite-sex Siblings
A-R	.63	.21*	.45	.46
R-P	.44	.54	.62	.56

Note: * MZ and DZ intraclass correlations are significantly different at $p \leq .05$; Table adapted from Rowe, 1983, p. 420.

child can only react to what he or she sees in his/her own mind, irrespective of the objective reality that surrounds them.

Daniels, Dunn, Furstenburg, and Plomin (1985) undertook a large study examining parent and offspring perceptions to determine if siblings from the same family perceive parental, sibling, and peer relationships differently. They then related the sibling perceptions to their self-rating of emotional adjustment. Their sample consisted of 348 families with information on at least two siblings (99 brother-pairs, 87 sister-pairs, and 162 brother-sister pairs). Siblings ranged in age from 11 to 17 years, with a mean age of 13.7 years. The age range of the parents of siblings was 27 to 73 years, the mean age being 39.6 years. Each sibling and mother was separately interviewed by telephone and rated on three behavioural adjustment scales. These scales were Parental Perception of Emotional Distress, Parental Perception of Delinquency, and Parental Perception of Disobedience. For the children, the scales were Self-Perception of Emotional Distress, Self-Perception of Delinquency, and Self-Perception of Dissatisfaction. Also obtained was a teacher report of Disobedience, and finally, a parent-sibling-teacher aggregate score of Disobedience. Nine environmental measure scores were obtained for each mother and child. These were Family Cooperation, Family

Stress, Parental Rule Expectations, Parental Chore Expectations, Maternal Closeness, Parental Closeness, Child's Say in Decisions, Sibling Friendliness, and Peer Friendliness.

Their findings indicate that parents appear to perceive that they treat their two children similarly. Table 2.3 presents the sibling intraclass correlations (from Daniels *et al.*, 1985, p.770). In contrast to parents, children do not perceive treatment by their parents to be similar. This is indicated by the lower intraclass correlations of each parent rated by each child. The sibling intraclass correlations on the adjustment measure indicate that parents, each sibling's teacher, and the children perceive themselves and each other to be quite different. The median intraclass correlation for these measures is .21. Sex, age, or birth order appeared to have little effect on differential sibling experience. Daniels *et al.* also add that although several intraclass correlations were significant, only 1% to 4% of the variance in the environmental measure scores was accounted for.

Difference scores were then calculated by subtracting the score for one sibling for each measure from his/her co-sibling's score. These signed differences of sibling adjustment were then regressed on parental treatment scores.

Table 2.3

Sibling Intraclass Correlations for Environmental and Adjustment Measures for All Types of Brother-Sister Pairings

Measures	♀♀ Pairs	♂♂ Pairs	♂♀ Pairs	Total Sample
Parents' perception of family environment:				
Parental chore expectations	.50*	.76*	.23*	.49*
Maternal closeness	.38*	.45*	.32*	.38*
Paternal closeness	.48*	.45*	.47*	.49*
Child's say in decisions	.66*	.68*	.61*	.65*
Sibling friendliness	.41*	.22*	.44*	.38*
Peer friendliness	.27*	.32*	.21*	.25*
Siblings' perception of family environment:				
Family cooperation	.14	.17*	.18*	.17*
Family stress	.31*	.22*	.32*	.29*
Parental rule expectations	.19*	.15	.19*	.18*
Parental chore expectations	.28*	.49*	.00	.21*
Maternal closeness	.27*	.26*	.09*	.19*
Paternal closeness	.35*	.33*	.11*	.26*
Child's say in decisions	.16*	.31*	.11*	.18*
Sibling friendliness	.34*	.22*	.16*	.22*
Peer friendliness	.25*	.10	.02	.09*

Parents' perception of child's adjustment:				
Emotional distress	.39*	.30*	.26*	.31*
Delinquency	.11	.43*	.08	.23*
Disobedience	.23*	.42*	.18*	.28*
Siblings' perception of their own adjustment:				
Emotional distress	.26*	.10	.03	.12*
Delinquency	.39*	.29*	.06	.21*
Dissatisfaction	.20*	.31*	.11*	.20*
Teacher's perception of their students' disobedience	.06	.00	.23*	.14*
Parent-sibling-teacher aggregate score of disobedience	.09	.27	.18*	.22*
N	64-87	74-99	122-163	299

Note: * $p \leq .05$; Table from Daniels, Dunn, Furstenburg, & Plomin, 1985, p. 770.

The signed difference assesses both the amount and the direction of the sibling differences. The first set of multiple regressions showed that differences between parental reports of each sibling's experiences explained 6% to 13% of the variance in sibling adjustment differences.

The variables Differential Maternal Closeness, Differential Peer Friendliness, and Differential Child's Say in Family Decisions emerged as the primary predictors of Differential Sibling Adjustment. The second set of analyses showed that differences between sibling reports of their experiences explained 4% to 11% of the variance in the sibling adjustment differences. This was as reported by themselves and by each of their teachers, but not by their parents. Again, Differential Maternal Closeness, Differential Peer Friendliness, and Differential Sibling Friendliness emerged as primary predictors.

Measuring Nonshared Environment

Cognizant of the evidence that perceptions are the main source of nonshared environmental influences, Daniels and Plomin (1985) developed the first measure designed to specifically assess aspects of nonshared environmental influence. They called it the "Sibling Inventory of Differential Experience" or SIDE. The SIDE was designed to tap a broad domain of socio-affective perceptions of experiences that may differ between siblings. The phrasing of the items forces individuals to respond by averaging over the years when they were growing up and living at home (p.749). The SIDE contains 73 items that assess four general categories of differential experience. The first is Differential Sibling Interaction, whose items tap the four underlying factors of Antagonism, Caretaking, Jealousy, and Closeness. The second is Differential Parental Treatment, which is answered separately for mothers and fathers. These items assess the two underlying factors of affection and control. The third category is Differential Peer Characteristics, whose items tap into three underlying dimensions of Orientation Toward College, Delinquency, and Popularity. The final category is Events Specific to the Individual, whose items assess experiences unique to one or the other of the siblings. For example, this category includes items on boyfriend-girlfriend relationships, relatives, divorce, death of a loved one, etc. See Daniels and Plomin (1985) for a full description of these categories.

Each SIDE item is answered on a five-point scale designed to lead to relative scoring of differential experience. Each sibling responds that he or she is more or less this way in a particular regard relative to his or her sibling. This scaling procedure provides information concerning the amount and direction of differential experience. Reported sibling agreements for perceptions ranged from -.39 to -.79. These negative intraclass correlations reflect sibling agreement. According to Daniels and Plomin, negative relationships also indicate that the SIDE measures sibling differences as opposed to similarities.

Relation of the SIDE to Differential Personality

Daniels and Plomin (1985) administered the SIDE to 396 sibling pairs (190 brother-sister pairs, 124 sister pairs, and 82 brother pairs). Their average age was 18.1 years. There were 226 first-second born pairs, 61 second-third born pairs, 41 first-third born pairs, and 68 pairs were of a variety of different birth orders. A total of 171 adoptees and 225 biological siblings composed their sample.

Examination of the sibling intraclass correlations shows greater similarity for perceived parental treatment than for other categories of differential experience. Furthermore, sibling interaction and peer group characteristics are greater sources of perceived differential experience than is parental treatment. The variances in scale scores also indicate considerable variability in differential sibling experience that suggests that siblings in some families share similar environments, whereas other siblings perceive their experiences to be quite different.

Daniels and Plomin also tested if differential sibling experience itself shows a genetic influence. The SIDE would reflect genetic differences if the intraclass correlations are lower for adoptive siblings (who are uncorrelated genetically) than for biological siblings (who share 50% of their genes on average). The intraclass correlation for adoptive siblings turned out to be larger than those for the biological siblings (-.79 *vs* -.69 respectively), although the difference was not statistically significant. They concluded that the SIDE scales do not show any genetic influence and that the origin of differential sibling perceptual experiences measured by the SIDE is environmental.

The effect of birth order and age was examined by correlating these variables with the four SIDE scales. Significant correlations were reported between birth order and Differential College Orientation, with earlier born siblings being slightly more likely to belong to a college bound group (-.12). Age was also significantly correlated with Differential Peer Popularity in that younger siblings were more likely to belong to a more popular peer group (-

.18). They found that opposite-sex sibling pairs perceive significantly more differential experiences than do same-sex pairs for Parental Control and Peer Popularity. Otherwise, sex has little effect on perceived differences. The last variable investigated was whether the absolute amount of sibling differential experience varied with developmental stage. They divided the sample into two groups: adolescent siblings still living at home (aged 12 to 17 years) and young adult siblings living apart (aged 18 to 28 years). Only one significant mean difference appeared. Younger siblings still living at home tend to perceive more differences on the sibling closeness scale than do older siblings who are both living away.

A separate study by Daniels (1986) examined the relationship between differential sibling experiences as measured by the SIDE and differences in sibling temperament as measured by the EAS Temperament Inventory. The EAS Temperament Inventory contains the following scales: Emotionality-Anger, Emotionality-Fear, Emotionality-Distress, Activity, Sociability, and Shyness. In addition, subjects were asked how many years of education they expected to complete and what career expectations they expected to achieve. Her sample consisted of 50 biological and 98 adoptive sibling pairs. The siblings ranged in age from 12 to 28 years; the mean age was 17.96 years. Of the

148 sibling pairs, 61 were opposite-sex and 87 were same-sex (35 brother-pairs and 52 sister-pairs).

Sibling correlations for personality and career expectations ranged from .14 to .21, indicating low sibling resemblance. However, biological sibling correlations tended to be higher than adoptive sibling correlations suggesting that some genetic variance is involved, although it may not be significant. The family constellation variables of gender, age, and birth order accounted for little of the variance (1% to 5%) in personality. Females reported greater Sociability and Emotionality-Fear than did males. Males reported greater Shyness and expected more years of education than did females. Age showed significant negative correlations with Sociability and Emotionality-Anger.

Personality differences were regressed on SIDE scale differences. It was found that the sibling that reported greater Sibling Jealousy also experienced greater Emotionality-Anger. The sibling who reported more Sibling Antagonism also experienced greater Emotionality-Fear. Furthermore, the sibling that reported more Sibling Closeness also appeared to be more Sociable, and the sibling that experienced greater Caretaking also reported less Shyness. Only one significant regression was found with the

SIDE parental treatment scales. Differential Paternal Affection was predictive of Siblings' Expected Occupation ($R = .36$, $R^2_{ADJ} = .09$, $p \leq .05$). Several of the SIDE peer characteristics scales were significant predictors of differential temperament as indicated by significant standardized regression coeeficients. The sibling that showed less of an Orientation Toward College also reported more Emotionality-Fear and more Emotionality-Distress. The sibling belonging to a more Popular Peer Group also exhibited greater Sociability. Finally, the sibling whose peer group showed greater Orientation Toward College was also the one who expected to complete more Years of Education and to achieve a higher Occupational Position. The predictors account for 6% to 26% of the variance in the sibling personality measures and educational and attainment scales.

Baker and Daniels (1990) recently presented more research employing the SIDE. A sample of 81 MZ and 37 DZ twin pairs completed the SIDE, the Eysenck Personality Questionnaire (EPQ; Eysenck & Eysenck, 1975), the Bem Sex Role Inventory (BSRI; Bem, 1974), the Affect Intensity Measure (AIM; Larsen & Diener, 1987) and the Zung Self-Rating Depression Scale (Zung, 1965). They had two research questions. The first was to determine the degree of genetic influence on the SIDE scales. They reasoned that if DZs perceive greater differential experience than MZs, this would suggest the presence of genetic factors in the SIDE measures. This is because MZ differences can only be attributable to nonshared factors, whereas DZ differences can be due to nonshared environmental factors and genetic differences. However, if the MZ-DZ comparison is much larger than the biological-adoptive sibling comparison, epistasis or special twin environmental influences (or both) must be considered.

The second objective of this study was to determine if any systematic relationship existed between the SIDE scales and the personality and affect scales in a sample of MZ twin pairs. Baker and Daniels reasoned that regardless of any genetic effects that may be present in the SIDE, any significant associations between the SIDE and MZ personality differences can only be due to nonshared environmental effects. Their results are presented in Table 2.4.

Multivariate analyses of variance revealed significant differences between MZ and DZ twin respondents for all the SIDE Differential Sibling Interaction, Differential Parental Treatment, and Differential Peer Group Influences subscales. MZ pairs consistently reported significantly fewer differences than DZ pairs for all but one scale. Comparison of these scores to scores obtained from biological and

Table 2.4

Significant Standardized Partial Regression Coefficients (β) From Analyses With Significant Multiple Correlations Among MZ Personality and Affect Differences and Relative Scores on SIDE Scales

SIDE Scale	Personality/Affect Measure	β
Sibling Interaction:		
Sibling Antagonism	Masculinity	.247*
Sibling Caretaking	Masculinity	.252*
Sibling Jealousy	Affect Intensity Measure	.305*
Paternal Treatment:		
Paternal Control	Zung Depression	-.467*
Paternal Control	Affect Balance Scale	.397*
Maternal Control	Zung Depression	.397*
Maternal Control	Affect Balance Scale	-.564*
Peer-group Characteristics:		
Peer Popularity	Extraversion	.376
Peer Popularity	Affect Balance Scale	.360

Note: * $p \leq .05$; Table from Baker and Daniels, 1990, p. 107.

adoptive siblings (from Daniels & Plomin, 1985) showed that SIDE scores generally decrease (less differential experience) with increasing genetic relatedness. With the exception of the parental treatment scales, adoptive siblings consistently reported far more differences than MZ twins, with DZ and nontwin siblings' reports somewhere in between. Furthermore, the magnitude of the difference between MZ and DZ scores is greater than the differences observed between biological and adoptive siblings. This observation implies that the SIDE may show greater genetic influence than previously thought. The SIDE may not, therefore, be a pure measure of the environment but may instead partially reflect inherited personality differences between siblings.

Differential personality and affect were then regressed on environmental differences from the MZ twins only. It was found that parental treatment differences were most strongly predictive of differences in depression and psychological well-being.

Summary and Evaluation

This series of research papers has provided evidence that nonshared environmental effects are perceptual; measurable; and are related to some aspects of personality functioning. What is most striking about this research is the lack of any strong relationships between nonshared environmental effects and differential personality. The relationships reported are at best moderate, accounting for little more than 30% of the variance. This lack of strong relationships can be due to a number of factors. Perhaps the theory that has guided this research is deficient in some way. However, before commencing on any theoretical reformulations, some thought must be given to the methodological aspects of the research purporting to test the theory. In reviewing these research reports, two fundamental deficiencies become evident.

The first issue is the use of signed difference scores. Many have warned that using difference scores are difficult to interpret (Bereiter, 1967; Gardner & Neufeld, 1987). If signed difference scores are problematical, how might these findings be interpreted? Second, the research to date is not very comprehensive. Studies have primarily hinged on the SIDE as the measure of the nonshared environment, and it is not clear if the SIDE dimensions adequately sample all content domains. Furhtermore, only a limited number of personality or affect measures have been employed. A much more comprehensive study employing multiple and overlapping measures is clearly necessary.

CHAPTER III

RESOLUTIONS, REFORMULATIONS, AND IMPLICATIONS

Signed Versus Absolute Value Difference Scores

Conventional wisdom dictates that the use of simple signed difference scores is problematical because they are plagued with statistical and conceptual difficulties. However, these difficulties are more pertinent to studies of *change over time*. Change (d) is measured by subtracting two measurements; one taken at Time 1 (t1) and the other at Time 2 (t2). Computation of the score does not change when the *difference* between two siblings becomes the focus. A sibling difference score (D) is the subtraction of one sibling's score (SIB1) from his/her co-sibling's score (SIB2). The signed difference score indicates the size and direction of the sibling difference. However, the change in focus to siblings leads to some methodological and conceptual reformulations that mitigate many of the problems plaguing the use of differences over time.

Computation of a change or difference score ($d = t_1 - t_2$ or D = SIB1 - SIB2) yields a signed difference value. In the case of studying change the sign of the value is of utmost importance because it gives information as to the direction of the change. Did the person perform better (+)

or worse (-) from Time 1 to Time 2. However, the valance of the difference is not of any great importance in studies of sibling differences. The sign is arbitrary. The sign is interpretable only if sibling assignment was systematic. For example, when studying autistic and non-autistic siblings (assuming only one afflicted sibling per pair), all the afflicted siblings should be assigned to be Sibling B. The differences between the two siblings would yield the degree of deficit compared to his/her non-autistic co-sibling. Otherwise, knowing which sibling scored greater than the other contains no useable information. All that is necessary to know is whether the siblings differ, and if so, by how much.

Gardner and Neufeld (1987) showed that the use of signed difference scores in correlational analyses can yield a number of very different results. One of the correlations they discuss is the correlation of change in one measure ($d = t1 - t2$) with the change in another measure ($d' = t1' - t2'$). This correlation is of the most interest because the intent of the present research is to correlate sibling personality differences with differential experience.

Gardner and Neufeld show that the magnitude of $r_{dd'}$ is dependent on the variabilities of the change scores themselves. In studies of change over time, the sign of the differences is important and conveys meaningful information. With studies of sibling differences, the sign contains no meaningful information. Retention of the sign will artificially inflate the variance of the scores used in the correlations and lead to erroneous results. The sign must be removed by taking the absolute value of the difference, but only after the siblings have been randomly designated Sibling A or Sibling B. Gardner and Neufeld also showed that decreases in either test-retest correlations ($r_{t1\,t2}$ or $r_{t1'\cdot t2'}$) will lower the magnitude of $r_{d\,d'}$. They demonstrate that a correlation of .75 can have three different interpretations when M, where $M = S_{t1}/S_{t2}$ (with S being the square root of the sum of squared deviations from the mean) and L, where $L = S_{t1'}/S_{t2'}$ are set at different values. The worst case occurs when M = 4 and L = 4 (large and equal relative variances). The most stable case is where both M and L are equal to unity (small and equal relative variances). Translated into the language of a sibling study, the most stable case occurs when Sibling A and B show equal variability on their environmental (L) and behavioural measures (M). As such, it follows that if the siblings show equal variability on the measures prior to computation of the difference scores, correlations based on the difference scores will be interpretable.

Three Dilemmas

Bereiter (1963) discusses three additional problems with using signed difference scores. The first he calls the *over-correction-under-correction dilemma* that refers to the fact that the change score (t1 - t2) is often negatively correlated with the pre-test score (t1). For example, the higher the pre-test scores, the lower the change scores and *vice-versa*. Initial thinking was that the sharing of errors of measurement in the change and pre-test scores was the basis for this phenomenon. However, this correlation is not always negative under certain conditions nor can it be assumed to be attributable to measurement errors (Gardner & Neufeld, 1987). The issue is not what the cause of this negative correlation may be, but how might this difficulty affect the study of sibling differences? The impact would be low because the central question for sibling difference studies is not whether one sibling's behaviour is related to the difference between both siblings' behaviour. The question of interest is the relationship between behavioural differences and environmental differences.

The second dilemma that Bereiter discusses is the *unreliability-invalidity dilemma*. This is concerned with the low reliability of the change score. Bereiter presents the formula for the reliability of the differences and demonstrates that the reliabilities of the differences decrease as the correlation between pre-test (t1) and post-test (t2) increases. Translation of the dilemma into the language of a sibling difference study nullifies the problem. If Sibling 1 and Sibling 2 are highly correlated on some measure (meaning that they are very similar), the differences between them would be very small and unreliable. It is expected that small differences would be rather unreliable. Even if the small difference is reliable (because of a large sample size), it is of limited interest. This is because it would account for very little of the variance and is liable to over-interpretation.

The final dilemma that Bereiter discusses is the *physicalism-subjectivism dilemma*. He argued that a measure of change, defined as the difference between scores taken on two different occasions, is difficult to interpret. For example, he suggests that a low test/retest correlation indicates that the test was not consistently measuring the same phenomena on both occasions. Again, this dilemma has no real bearing when examining sibling differences. This dilemma stems from a problem of time in a repeated measures design - does the instrument measure the same thing at both times? This is a reasonable concern, given that such difficulties as carry-over effects, etc. can clearly affect a person's response on a measure a second time. The examination of sibling differences presents no time element. A sibling is not tested twice and cannot be plagued with carry-over effects.

Exogenous Versus Endogenous Measures of the Environment

Recall that Plomin and Bergeman (1991) wrote that the typical psychological approach to the environment is that it is wholly independent of the individual or organism. However, they make the case that self-report measures of the environment blur the distinction between the environment and the organism. Self-perceptions filter through feelings, personality, and the cognitions of the individual to be incorporated into the measure of the environment (p. 373). As such, they suggest that the environmental measures themselves be considered as phenotypes and analyzed and broken down into genetic and environmental effects. Their reasoning for treating an environmental measure as a phenotype is, "Environments have no DNA and can show no genetic influences. *Measures* of the environment...may be perfused with characteristics of individuals..." (Plomin & Bergman, 1991, p. 374, italics theirs).

Plomin and Bergman's (1991) paper reviews all available evidence for a genetic influence on many widely used measures of the environment. They found substantial genetic influences on the Home Observation for Measures of the Environment, the Family Environment Scales, the Social Readjustment Rating Scale of Life Events, and the SIDE. Genetic influence was also found for a number of distal measures such as socio-economic status and education. This is not surprising because these variables are significantly related to cognitive ability which itself has a substantial heritable component. A genetic influence was detected regardless of whether the environmental measure was used in a twin or adoption design; who was the target of the study (parents or children); or if the measures were objective or subjective in nature.

The main implication of finding a substantial genetic influence on an environmental measure is the determination of the direction of effects. Assume that a phenotypic correlation was found between a personality trait (say, anxiety) and an environmental variable (say, child's perception of parental favouritism). If the environmental variable has a small heritable component, it is possible to assume that the child's environmental perception is objective. We can then conclude that the child's view of his/her parents' treatment of self and co-sibling is a true reflection of reality and that these factors directly affect anxiety levels. Note that the direction of effects is clear, although not entirely conclusive. It is possible that behavioural differences within pairs of siblings originate from prior experiences with which the contemporaneous measure of nonshared environment is correlated (Plomin & Daniels, p.13).

If, on the other hand, the environmental measure shows a substantial genetic influence, then two conclusions are possible. First, it could be that a child's pre-existing tendency to anxiety filters or alters perceptions of parental treatment. In this case, the same genetic or environmental factors may underlie both anxiety and perceptions of parental treatment. Alternatively, environmental perceptions may be affected by some other genetically based factors unrelated to the behaviour currently under study (e.g., cognitive ability). With these two cases the direction of effects is quite unclear.

Questions of the direction of effects are far from being answered and go beyond the current state of knowledge. Research here will require the use of multivariate biometric models (Hewitt, 1991). McGue, Bouchard, Lykken, Finkel (1991), Boomsma and Molenaar (1991), and Wachs (1991) Tellegen (1991) present a number of hypothetical models. They are all somewhat different, indicating the lack of a unified theory. Before considering the use or development of such models, more background work remains to be done.

As such, in the context of nonshared environmental research, the first

> "... reasonable priority for research would be to identify relationships between nonshared environment and sibling differences in behavior...and to worry about the direction of effects only *after* such relationships are found" (Plomin & Daniels, 1987, p. 15).

The second priority for research would be to classify environmental measures as exogenous or endogenous. Plomin and Bergeman (1991) suggest that,

> "Research in this vein may prove useful in a practical sense in identifying environmental measures that are relatively free of genetic influence. Environmental measures free of genetic influence would seem more likely to show effects of intervention, and they would permit more straightforward interpretations of environmental influence in other research using measures of the environment... Sorting out the extent of genetic involvement might provide clues as to the mechanisms for genetic influence..." (p. 384-385).

Summary

The essence of this discussion is that an environmental measure does not have to be truly endogenous to an individual in order to be useful for studies of where and how the environment is related to behaviour. The environment is perceived and is responded to by an individual, whether the person is passively affected by the environment or whether the person reacts to the environment in reference to his or her own genetic proclivities. The first research step is to identify what relationships exist between environment and behaviour. This must be done in a methodologically powerful way and the research must be comprehensive so that many domains of experience are covered. No less important is the determination of the extent to which genetics influence perceptions of the environment. Once these first two basic questions are adequately documented, they can be combined to address questions of gene-environment interactions and correlations.

The study of human personality is an ideal place to begin the study of the environment and behaviour because so much of the variance in personality is attributable to environmental effects, particularly those of the nonshared variety. Early research attempts to identify relationships between nonshared environmental influences and personality differences demonstrated that such research is feasible. This research has also brought to light some important methodological difficulties. In particular, these problems include the use of signed difference scores in a correlational analysis, and the use of a limited number of environmental and personality measures. The present study attempts to remedy these problems.

CHAPTER IV

BEHAVIORAL GENETIC ANALYSIS OF PERSONALITY & THE ENVIRONMENT

Behaviour genetic research has developed along two general lines of inquiry. The first has been the development and application of techniques to estimate genetic and environmental effects on behaviour. The second general line grew out of a response to findings in the first, that nonshared environmental influences underlie a large proportion of the variance in personality. This research has centred on trying to identify sources of nonshared environmental influence that are related to differences in sibling's personalities. These two streams of research can now be combined into a single study that can take advantage of the most recent developments in the field. The present investigation will first examine the extent of genetic and environmental contributions to normal personality and liability to personality disorder. However, unlike most standard quantitative genetic analyses, an effort will be made to es[illegible] the magnitude of nonadditive genetic influence where [illegible] its presence is indicated. These analyses will be carried out not only on measures of personality, but are extended to encompass measures of the environment as well. This research will also extend the analysis beyond the univariate case. Where possible, multivariate genetic analyses will be performed that are designed to test for a common genetic and/or a common environmental etiology that underlies a set of related variables. Multivariate analyses such as these prevent variables being studied in isolation, but in the context of other psychologically related and meaningful variables. This state of affairs better represents how behaviour might actually operate. In sum, the main purpose of the quantitative genetic analyses is to obtain a comprehensive picture of the etiology of personality that covers as many areas of personality, the environment, and aspects of the quantitative genetic model as is possible. This research is also designed to examine the nature of the relationships between different traits.

The second line of research to be presented here follows from the results of the quantitative genetic analyses. This is the identification of nonshared environmental effects related to personality. If a sizeable nonshared environmental component is identified among the personality traits used in the present study, an attempt will be made to identify what these influences might be. This research will incorporate the recent theoretical, rational, and empirical developments in this area of research. As such, this research will differ in a number of important ways from the reports reviewed earlier. First, to be comprehensive, this investigation will employ a large number of measures of personality, personality disorder, and the environment. Second, absolute value difference scores comprise the primary data instead of signed difference scores. Furthermore, the validity of any relationships will be checked with the sibling ratio of variances (M & L). Finally, the present investigation will examine data from three different kinships in one study. The examination of data from three different sibling types provides a greater range of effects that may aid in the detection of effects. Furthermore, this allows for comparisons between the groups. This may highlight a systematic zygosity effect which might provide insight into the nature of nonshared environmental effects and their operation.

General Method

Subjects

The sample consisted of 203 same-sex sibling pairs with a distinct female bias, typical for volunteer twin studies. This sample includes 89 monozygotic (MZ) twin pairs (71 sister pairs: M age = 23.90 years, SD = 6.93; and 18 brother pairs: M age = 23.95 years; SD = 5.65) and 49 dizygotic (DZ) twin pairs (40 sister pairs: M age = 24.82, SD = 7.48; 9 brother pairs: M age = 24.07 years, SD = 7.48. Also included are 65 non-twin (NT) sibling pairs (51 sister pairs, Sibling A: M age = 24.87 years, SD = 5.94; Sibling B: M age = 23.34 years, SD = 5.23; and 14 brother pairs: Sibling A: M age = 22.79, SD = 3.57; Sibling B: M age = 22.35, SD = 3.56). The means for the male non-twin siblings appear odd because approximately only 5 months separate the siblings. Examination of the age distributions for these siblings explain this odd result. The distribution for Sibling A is more or less bell shaped (kurtosis = -.312, skewness = 1.060). However, the distribution of age for Sibling B is distinctly bimodal (kurtosis = -1.588, skewness = .187). This indicates that these male non-twins are at the extremes of the age distribution. The overall mean thus falls in between these two distibutions and is artificially low.

Zygosity determination was determined through a questionnaire designed by Nichols and Bilbro (1966). This includes questions concerning physical similarities and differences, as well as frequency of confusion of the twins by family members and others whilst growing up (see Appendix I). This method has a reported accuracy of at least 93% as compared to the results of DNA analysis (Kasriel and Eaves, 1976). Questionnaires are an acceptable method of diagnosing zygosity where blood-typing is not possible. In many cases, recent colour photographs provided supplementary evidence of zygosity.

Procedure

Nonadoptive twin and sibling pairs raised together in the same home were recruited through newspaper advertisements and media stories primarily from Vancouver, British Columbia; London, Ontario; and Calgary, Alberta. Two additional pairs were recruited from Ottawa, Ontario. Twin pairs were eligible for participation if they were at least 16 years of age and no older than 45 years of age at the time of participation. Participation required both siblings to participate at the same time. Potential participants responded to advertisements by telephone and were informed of the purposes of the study, what participation involved, and remuneration. In the case of non-twin siblings, they had the choice of any younger or older sibling in their family, though they were encouraged to select the sibling closest in age.

The subjects for the present study were a subset of participants in the University of Western Ontario Twin and Adoption Project which is devoted to behavioural genetic studies of cognitive ability and personality. Participation in the study involved a single three-hour on-site visit to the university campus or office. All sibling pairs read and signed an informed consent form, and completed the Minnesota Multiphasic Personality Inventory (MMPI; Hathaway & McKinley, 1983) and a test of intelligence (which is not pertinent to the present report). Subjects were also furnished with a package of additional questionnaires to complete at-home (described below).

Independent Variables

Although the determintion of the direction of effects is another issue, for conceptual convenience the traditional view that the environment impinges on the organism will be adopted here. This practice is not new, the precedent was set by similar research in this area. Implicit throughout the literature review in Chapter II is the assumption that a person's perceptions of his/her environment may have an affect on his/her personality. This basic assumption stems from Rowe's (1981, 1983) papers where he makes such statements as, "... perceptions of parenting, as well as parental practices, may have an influence on children..." (from Rowe, 1981, p.203). He also reviews earlier studies that suggest that children react most directly to their perceptions and summarizes that for example, perceptions of parenting are highly predictive of personality adjustment (Rowe, 1983, p.203). The assumption that the environment (real and perceived) directly influences personality and cognitive ability is further promugulated by Daniels (1986) work. Recall that she tried to predict personality differences between siblings with any differences in their perceived environment.

As such, aspects of the environment will comprise the independent variables. These variables come from four currently available measures of the environment. They are the Sibling Inventory of Differential Experience (SIDE; Daniels and Plomin, 1985), the Environmental Response Inventory (ERI; McKenchie, 1974), the Family Environment Scale (FES; Moos and Moos, 1986), and the Classroom Environment Scale (CES: Trickett and Moos, 1974). Each measure is briefly described below.

The Sibling Inventory of Differential Experience

The SIDE purports to assess four categories of differential sibling experience. The first is "Differential Sibling Interaction", whose 24 items tap the four underlying factors of Antagonism (SIBANT), Caretaking (SIBCARE), Jealousy (SIBJEAL), and Closeness (SIBCLO). The second is "Differential Parental Treatment", completed separately in reference to both mother and father. Its nine items assess the two underlying factors of Affection (MATAFF, PATAFF) and Control (MATCONT and PATCONT). The third category is

"Differential Peer Characteristics", whose 26 items tap into three underlying dimensions of Orientation Toward College (PEERCOL), Delinquency (PEERDEL), and Popularity (PEERPOP). The final category is "Events Specific to the Individual", whose 14 items assess experiences unique to one or the other of the siblings. For example, this category includes items on boyfriend-girlfriend relationships, relatives, divorce, death of a loved one, etc. These 14 scales are of single item format and have been deleted from the present study because their low psychometric reliability. The SIDE has become the central instrument of most, if not all investigations of nonshared environment to date. Its inclusion in the present study is mandatory for purposes of comparison and replication.

Each SIDE item is answered on a five-point scale, designed to lead to relative scoring of differential experience. Each sibling responds that he or she is more or less this way in a particular regard relative to his or her sibling. This scaling procedure provides information concerning the amount and direction of differential experience. The relative response can be recoded on a three-point scale to yield an absolute measure of differential sibling experience. The absolute scores indicate a sibling's perception of the amount of differential experience that exists between self and co-twin. Reported test-retest reliabilities of the 11 scales range from .70 to .94. Scale intercorrelations range from .01 to -.54, which implies that the sclaes are unrelated and each is measuring a unique aspect of the nonshared environment. Sibling agreements for perceptions range from -.39 to -.79. These negative intraclass correlations reflect sibling agreement. Subjects in the present study completed the items in reference to their home life as they were growing up with their parents or guardians. The SIDE items are presented in Appendix II.

The Environmental Response Inventory

The ERI purports to measure individual differences in the ways people think about and relate to the physical environment. This scale is unique in that it does not purport to be a totally exogenous measure of the environment and deliberately combines a person's attitudes with his or her environmental perceptions. Plomin and Bergeman (1991) call out for measures such as this. They write,

> "Most important, we need measures that move beyond the passive model of the individual as merely a receptacle for environmental influence to measures that can capture the individual's active selection, modification, and creation of environments - this lies

at the heart of the interface between nature and nurture." (p. 386).

The ERI intentionally assumes perceptions of the environment are filtered and coloured by one's personality and attitudes - and it is to these perceptions of the environment that we react. As a measure of the environment the ERI does not tap objective phenomena akin to number of books in the home or differential paternal treatment, but rather one's overall response to the environment as whole.

The ERI consists of a set of 184 statements tapping attitudes toward conservation, recreation and leisure activities, architecture and geography, science and technology, urban life and culture, aesthetic preferences, privacy and adaption. The subject indicates the extent to which a statement applies to self using a five-point Likert format where 5 = strongly agree and 1 = strongly disagree. The ERI items are presented in Appendix III.

These items form eight "environmental disposition" scores and one scale validity score. The eight environmental disposition scores are Pastoralism (P), Urbanism (UR), Environmental Adaption (EA), Stimulus Seeking (SS), Environmental Trust (ET), Antiquariarism (AN), Need for Privacy (NP), and Mechanical Orientation (MO).

Communality (CO) is the validity score. These scales are not well known and a short description taken from the manual (p. 2) is presented below:

Pastoralism. Opposition to land development; concern about population growth; preservation of natural resources, including open space; acceptance of natural forces as shapers of human life; sensitivity to pure environmental experiences; self sufficiency in the natural environment.
Urbanism. Enjoyment of high density living; appreciation of unusual and varied stimulus patterns of the city; interest in cultural life; enjoyment of interpersonal richness and diversity.
Environmental Adaption. Modification of the environment to satisfy needs and desires, and to provide comfort and leisure; opposition to government control over private land use; preference for highly designed or adapted environments; use of technology to solve environmental problems; preference for stylized environmental details.
Stimulus Seeking. Interest in travel and exploration of unusual places; enjoyment of complex and intense physical sensations; breadth of interests.
Environmental Trust. General environmental openness, responsiveness, and trust; competence in finding one's way about the environment *vs* fear of potentially dangerous environments; security of home; fear of being alone and

unprotected.

Antiquanarianism. Enjoyment of antiques and historical places; preference for traditional versus modern design; aesthetic sensitivity to man-made environments and to landscape; appreciation of cultural artifacts of earlier eras; tendency to collect objects for their emotional significance.

Need for Privacy. Need for physical isolation from stimuli; enjoyment of solitude; dislike of neighbours; need for freedom from distraction.

Mechanical Orientation. Interest in mechanics in its various forms; enjoyment in working with one's hands; interest in technological processes and basic principles of science; appreciation of the functional properties of objects.

Communality. A validity scale, tapping honest, attentive, and careful test-taking attitude, response to items in a statistically modal manner.

Split-half reliabilities for the environmental disposition scores range from .70 to .86 and .75 for the validity scale. Two week test-retest reliabilities range from .81 to .90 for the environmental disposition scales and .81 for the validity scale. Instructions to the subjects in the present study were to answer the questions in reference to their most prevalent attitudes during their life.

The Family Environment Scale

Subjects completed Form R of the FES. This form measures people's perceptions of their conjugal or nuclear family environment. The 90 true-false items of this scale assess three underlying domains. The first is the "Relationship" dimension defined by the Cohesion (FAMC), Expressiveness (FAMEX), and Conflict (FAMCON) subscales. The second dimension is "Personal Growth", or goal orientation, defined by the Independence (FAMIND), Achievement Orientation (FAMAO), Intellectual-Cultural Orientation (FAMICO), Active-Recreational Orientation (FAMARO), and Moral-Religious Emphasis (FAMMRE) subscales. The final superordinate dimension is "System Maintenance", defined by the Organization (FAMORG) and Control (FAMCTL) subscales. Six week test-retest reliabilities range from .72 to .92. Provided below is a short description for each of the subscales taken directly from the manual (Moos & Moos, 1986, pp. 2-3).

Relationship Dimensions

Cohesion. The degree of commitment, help, and support family members provide for one another.

Expressiveness. The extent to which family members are encouraged to act openly and to express their feelings directly.

Conflict. The amount of openly expressed anger, aggression, and conflict among family members.

Personal Growth Dimensions

Independence. The extent to which family members are assertive, are self-sufficient, and make their own decisions.

Achievement Orientation. The extent to which activities (such as school and work) are cast into an achievement-oriented or competitive framework.

Intellectual-Cultural Orientation. The degree of interest in political, social, intellectual, and cultural activities

Active-Recreational Orientation. The extent of participation in social and recreational activities.

Moral-Religious Emphasis. The degree of emphasis on ethical and religious issues.

Systems Maintenance Dimensions

Organization. The degree of importance of clear organization and structure in planning family activities and responsibilities

Control. The extent to which set rules and procedures are used to run family life.

A full description of the dimensions and subscales is provided by Moos and Moos (1986). The internal-consistency reliabilities reported for the ten subscales range from .61 to .78, and the 12 month test-retest reliabilities range from .52 to .89. Subjects completed the items in reference to the time when they were growing up at home with their parents or guardians. The FES items are presented in Appendix IV.

The Classroom Environment Scale

Most of one's early life is usually spent in elementary and secondary school, and in many cases college. Oddly enough, the previous studies of nonshared environment neglected to include school variables. Form R of the CES purports to measure students' and teachers' perceptions of their current classrooms with 90 true-false scored items. There are nine CES subscales that tap three superordinate domains. The first domain is the "Relationship" dimension measured by Involvement (SCHI), Affiliation (SCHA), and Teacher Support (SCHTS) subscales. The second domain comprises "Personal Growth" or "Goal Orientation" defined by Task Orientation (SCHTO) and the Competition (SCHC) subscales. The final dimension is known as the "System Maintenance and Change" dimension. Four subscales define this dimension: Order and Organization (SCHOO), Rule Clarity (SCHRC), Teacher Control (SCHTC), and Innovation (SCHINN). Due to the great variety of types and extent of schooling, subjects were instructed to think back to any time in their school career. They were instructed to respond in reference to whichever teacher or class they could best recall. Presented below are short descriptions each of the subscales (from Trickett & Moos, 1974, pp. 2-3). The CES items are presented in Appendix V.

Relationship Dimensions

Involvement. The extent to which students are attentive and interested in class activities, participate in discussions, and do additional work on their own.

Affiliation. The level of friendship students feel for each other, as expressed by getting to know each other, helping each other with homework, and enjoying working together.

Teacher Support. The amount of help and friendship the teacher manifests toward students; how much the teacher talks openly with students; trusts them, and is interested in their ideas.

Personal Growth/Goal Orientation

Task Orientation. The amount of emphasis on completing planned activities and staying on subject matter.

Competition. How much students compete with each other for grades and recognition and how hard it is to achieve good grades.

System Maintenance and Change Dimensions

Order and Organization. The emphasis on students behaving in an orderly and polite manner and the overall organization of assignments and classroom activities.

Rule Clarity. The emphasis on establishing and following a clear set of rules and on students knowing what the consequences will be if they do not follow them; the extent to which the teacher is consistent in dealing with students who break rules.

Teacher Control. How strict the teacher is in enforcing the rules, the severity of punishment for rule infractions, and how much students get into trouble in the class.

Innovation. How much students contribute to planning classroom activities, and the extent to which the teacher uses new techniques and encourages creative thinking.

Additional Items from the Twin Questionnaire

In addition to the measures described above, twins and siblings were asked four additional questions. These are: to list the number of ways they are similar (e.g., attitudes, interests, personalities) to one another; the number of ways in which they differ (e.g., attitudes, interests, personalities); the number of serious illnesses or accidents they have had that their sibling has not; and the number of times they had been separated from each other as children for more than a one month duration. The complete twin questionnaire is provided in Appendix I.

Dependent Variables

The Personality Research Form

Jackson's (1986) Personality Research Form (PRF) was used as the measure of normal personality. Subjects completed the PRF - Form E, following Jackson's (1986) instructions. Form E was chosen because it only takes approximately 30 to 45 minutes for subjects to complete, minimizing possible subject fatigue. Furthermore, besides containing all 22 scales, it has complete norming. The PRF contains 20 trait scales and 2 validity scales providing a detailed and comprehensive assessment of normal personality. The 20 trait scales are Abasement (AB), Achievement (AC), Affiliation (AF), Aggression (AG), Autonomy (AU), Dominance (DO), Endurance (EN), Exhibition (EX), Harm Avoidance (HA), Impulsivity (IM), Nurturance (NU), Order (OR), Play (PL), Social Recognition (SR), Understanding (UN), Abasement (AB), Change (CH), Cognitive Structure (CS), Defendence (DE), Sentience (ST), and Succorance (SU). Two validity scales are Infrequency (IN) and Desirability (DY). PRF odd-even reliability ranges from .50 to .91 on a college sample. Validity coefficients based on self-rating and roommate ratings range from .27 to .74, with a mean of .52. Jackson (1986) provides full information on the PRF's psychometric properties.

The Minnesota Multiphasic Personality Inventory

The subjects also completed the Minnesota Multiphasic Personality Inventory (MMPI; Hathaway & McKinley, 1983) as a measure of liability to personality disorder. The MMPI differs from the PRF in that it is designed to objectively assess the major personality characteristics that affect personal and social adjustment. In other words, traits that are commonly characteristic of disabling psychological abnormality (p. 1). The MMPI scales are Hypochondriasis (Hy), Depression (D), Hysteria (Hy), Psychopathic Deviate (Pd), Masculinity-Femininity (Mf), Paranoia (Pa), Psychasthenia (Pt), Schizophrenia (Sc), Hypomania (Ma), and Social Introversion (Si). There are four validity scales: *?* (Cannot Say), Lie (L), Infrequency (F), and Defensiveness (K). Four special scales can also be derived: Anxiety (A), Repression (R), Ego Strength (Es), and MacAndrew Addiction Scale (Mac). Test-retest reliabilities range from .46 to .93 in a normal population and .36 to .93 in psychiatric patient populations. The *?* scale is the number of items left blank. Because all subjects were encouraged to complete every item on the MMPI, very few items were left blank, rendering the ? (Cannot Say) scale meaningless and it was dropped.

With the exception of the MMPI, all questionnaires were completed at-home and at the subject's convenience. Upon completion, they were returned by mail. Participants whose take-home package was not returned after two months were telephoned and politely reminded to complete and return it as soon as possible. Upon receipt, subjects received $20.00(CDN) as compensation for their time.

Once all questionnaires were returned for a pair, each sibling and co-sibling was randomly assigned to be either Sibling 1 or Sibling 2 of a pair and questionnaires were scored. Data analyses took place in three separate stages. The first stage consists of simple descriptive statistics for general information regarding sibling similarity and to highlight any peculiarities inherent in the data. The second stage involved quantitative genetic analyses using model-fitting techniques. The third and final stage consisted of stepwise multiple regression analyses to relate differential experience to personality differences. This procedure identifies what forms of differential environmental experience are related to sibling personality differences. Missing data were handled with pairwise deletions in each analysis. Due to the large number of questionnaires and scales used in the study, listwise deletions would have left very small sample sizes.

Preliminary Analyses

Each pair of siblings in this study yields two types of scores for each variable. The first is a raw scale score for each sibling and the second is a difference score. Difference scores were computed for every variable in each pair by subtracting Sibling 2's scale scores from Sibling 1's scale scores and taking the absolute value. The exception was the SIDE. Absolute value difference scores were computed only for the absolute SIDE scores. Recall that relative SIDE scores indicate the amount and direction (who is more or less this way in this regard) of differential experience. The difference between two relative scores is substantively uninterpretable as the amount and the direction of effects become confused and contradictory, especially when siblings do not agree. Absolute SIDE scale scores, however, indicate only the amount of perceived differential experience and the difference between two siblings' scores are readily interpretable.

Frequency distributions for each raw scale and difference score were examined for gross departures from normality. Positive skews were transformed by computing the square root of each score. A negative skew was transformed by computing the square of each value.

Descriptive Statistics and Examination of Kinship Differences

The mean and standard deviation for every scale was computed for each raw scale score based on twin and sibling individuals for each kinship. Twin and sibling individual statistics refer to statistics that include both siblings of a pair in its computation. The means and standard deviation of the difference scores were also computed for each kinship. One-way analysis of variance compared the means and variances between kinships. A *post-hoc* multiple comparison procedure (Newman-Keuls) tested for differences between MZ and DZ, MZ and NT, and DZ and NT individuals ($p \leq .05$, two-tailed). Typically, univariate t-tests are used. However, given the large number of variables and possible comparisons, some control for family-wise error rate was necessary. Testing the absolute size of the sibling differences was accomplished with a variant of the t-test. This test would provide an indication of whether the observed sibling differences were statistically different from zero. Kenny (1987) gives the formula for the general form of t-test statistic as $t = (P_k - \mu) \div (S_k / \sqrt{N_k})$ where P_k

refers to the mean of the scale score differences computed for k pairs, S_k refers to the standard deviation of k pairs, and the term N_k refers to the total number of pairs that compose group k. The term μ refers to the size of the differences if the null hypothesis is true. To test for the existence of sibling differences, the value was set to zero (0.0). Control for family-wise error for these tests was made by dividing two-tailed α set at .05 by the total number of comparisons to be made ($.05 \div 82 = .00061$). This value of p is close to .0005, for which a table of critical *t*-values at $df = N_k - 1$ was readily available (e.g., Ferguson, 1981). As such, t_{OBT} was tested against $t_{CRITICAL}$ where $p \leq .0005$, two-tailed. Furthermore, although this correction is quite conservative in that it makes it more difficult to find differences significantly greater than zero, it is also desireable as any differences found are more likely to be genuine.

Sibling Resemblance for Personality and Environmental Perceptions

Sibling similarity was examined by correlating (Pearson's *r*) each sibling's transformed scores with his/her co-twins'. The test of statistical significance of each *r* was set at

.05 using a two-tailed test. The question of how similar siblings are within each zygosity as compared to siblings of another zygosity was examined by comparing the magnitude of correlations between groups. Three sets of comparisons are possible: r_{MZ} *vs* r_{DZ}; r_{DZ} *vs* r_{NT}; and r_{MZ} *vs* r_{NT}. These comparisons were tested by converting the difference between r_{GROUP1} and r_{GROUP2} to *z* using Fisher's z_r transformation ($z_r = .5\log_e(1 + r) - .5\log_e(1 - r)$) divided by the standard error of the difference of z_r. The complete test is: $z = (z_{r1} - z_{r2}) \div \sqrt{1/(N_{GROUP1} - 3) + 1/(N_{GROUP2} - 3)}$. $z_{CRITICAL}$ is 1.96 with $p \leq .05$. Setting the alpha to .05 as opposed to correcting for family-wise error in this series of in this family of tests is quite liberal. This is desireable because one of the main assumptions of the twin method is that the environments of MZs are no more similar than DZs. To find no significant differences in the similarities for the environmental measures under these liberal conditions provides a very stong indication that no significant differences in similarites exist in a particular regard.

The effects of gender and age were evaluated by correlating these variables with each of the twin and sibling individual scores over the entire sample.

Heritability Analyses

The raw scale scores for the MZ and DZ twins were split into groups by zygosity (MZ or DZ) and further by sibling (Sibling 1 or Sibling 2). Distributions of full raw scores for each of these four groups were examined for gross departures from normality. Corrections by square root or natural logarithmic transformations were made until distributions with acceptable symmetry were obtained. McGue and Bouchard (1984) demonstrated that the presence of age and sex effects on a trait score can seriously bias heritability and environmentality estimates. Corrections for age and sex effects were made by computing standardized residual scores from the multiple regression of each score on age and sex. All further genetic analyses presented here are based on age- and sex-adjusted, transformed scores.

Model-Fitting Analyses

Covariance matrices were computed between a twin and his/her co-twin for MZ and DZ pairs with the computer program PRELIS (Jöreskog & Sörbom, 1989). A model-fitting approach was applied to these covariance matrices to estimate the proportion of the variance attributable to genetic and environmental factors. A number of reduced models that systematically remove the effects of a genetic or environmental influence to test the importance of its contribution to a trait (Neale *et al.*, 1989) were also fitted. The genetic models were fitted with the computer program LISREL (Jöreskog and Sörbom, 1989). The full ACE model was fitted first (Chapter 1). The obtained maximum likelihood parameter estimates (*h, c, e*) are squared to form the familiar h^2, c^2, and e^2 estimates. It is possible to test for nonadditive genetic effects in those scales that have a zero shared environmental component, and where the ratio of the MZ correlation to the DZ correlation is greater than 2. For these scales, a model specifying additive genetic variance (A), nonadditive genetic variance attributable to genetic dominance (D), and nonshared environmental variance (E) was tested. The obtained maximum likelihood parameter estimates (*h, d, e*) are squared to form estimates of h^2, d^2, and e^2. Sample LISREL program scripts for the full ACE and ADE models are presented in Appendices VI and VII.

Three reduced models were fitted that systematically removed a component of variance. The first was Model 2 (CE or DE only as appropriate) that predicts no additive genetic effect. Second was the Model 3 (AE or DE only as appropriate) that predicted no common environmental effect. The fourth and final model (E only) predicts no family resemblance. The χ^2 of each reduced model is subtracted from the χ^2 from the full model. A significant change in χ^2 between the full ACE or ADE model and the reduced model indicates that the remaining parameters cannot independently account for the variance. The goodness-of-fit of all models was determined using Akaike's (1970, 1987) Information Criterion (AIC = χ^2 - 2(df)) which gives an unbiased indication of fit in models with a small number of parameters (Bollen, 1989) and χ^2.

Multivariate Genetic Analyses

Where possible, multivariate biometric models will be fitted to PRF variables that have a statistically significant and psychologically meaningful correlation with MMPI variables. The purpose of these analyses is to illustrate an approach that will test whether or not common genetic or environmental factors underlie normal personality and liability to personality disorder. Simply put, to test whether or not any observed phenotypic correlation between MMPI and PRF variables can be attributed to an underlying genetic or environmental correlation.

The first step in these analyses is to compute Pearson correlations between each PRF variable and all MMPI variables based on scores obtained from MZ and DZ twins only. Any statistically significant and meaningful correlations from a psychological point-of-view between two variables will be subjected to a bivariate multivariate genetic analysis, as discussed in Chapter 1 and presented below in Figure 4.1. The model presented in Figure 4.1 allows for common additive genetic, shared environmental, and nonshared environmental influences. Unique additive genetic, shared environmental, and nonshared environmental influences are also catered for. Sample LISREL program script for this model is presented in Appendix VIII.

Goodness-of-fit is assessed by χ^2. Heritability and environmentality estimates for common and unique components are computed with the general formula: $h^2_{common} = h^2_c / (h^2_c + c^2_c + e^2_c)$, and $h^2_{unique} = h^2_u / (h^2_u + c^2_u + e^2_u)$. Non-zero heritability or environmentality coefficients for the common factors indicate the proportion of each variable's variance due to genetic or environmental factors that all the variables in the analysis have in common, or, are unique to the variables in the model.

Sibling Differential Experience Related to Sibling Personality Differences

Stepwise multiple regression was used to identify possible relationships between each personality difference variable and all differential experience variables. Each

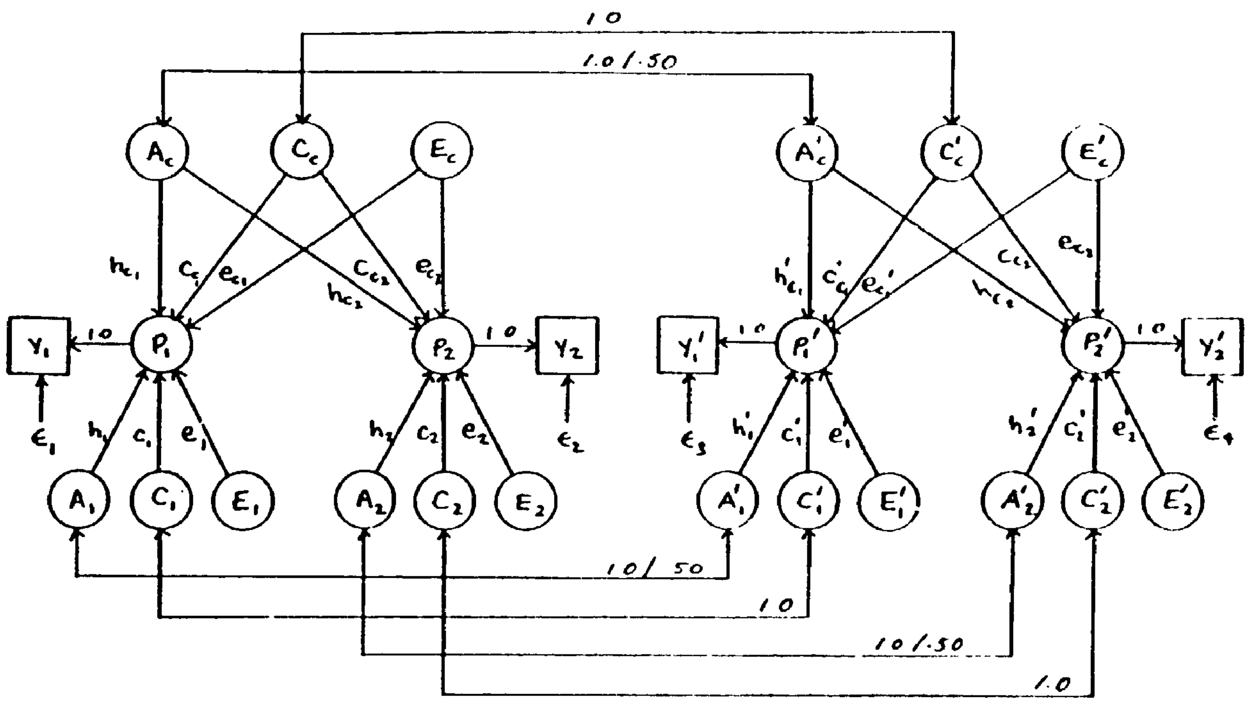


Figure 4.1. *Bivariate Biometric Model.* A_c, C_c, E_c denote the genetic variation, shared environmental variation, and nonshared environmental variation common to the phenotypes ($P_1, \ldots P_n$). The primes (′) denote the corresponding variables for the second twin. $Y_1, \ldots$ and Y_n denote observations on the first and second twins. Parameters h_{c1}, c_{c1}, $e_{c1}, \ldots h_{cn}$, c_{cn}, e_{cn} are the maximum likelihood parameter estimates which are used to form h^2_{c1}, c^2_{c1}, $e^2_{c1}, \ldots h^2_{cn}$, c^2_{cn}, e^2_{cn} estimates. A_1, C_1, $E_1, \ldots A_1$, C_1, E_1 denote the genetic variation, shared environmental variation, and nonshared environmental variation unique to the phenotypes ($P_1, \ldots P_n$). Parameters h_1, c_1, $e_1, \ldots h_n$, c_n, e_n are the maximum likelihood parameter estimates which are used to form h^2_1, c^2_1, $e^2_1, \ldots h^2_n$, c^2_n, e^2_n estimates. Standard LISREL notation has not been included for all latent and observed variables and parmeters for clarity.

transformed personality difference variable was regressed on all transformed environmental difference variables. Age differences and gender were also included as independent variables. These stepwise regressions were performed on the data obtained from the MZ, DZ, and NT samples separately.

Also computed at this time was the ratio of variances of the normalized difference scores, M and L. As discussed in Chapter III, the M and L statistics are useful in determining the validity and stability of difference scores. M is the ratio of the standard deviations of sibling 1 to sibling 2 for the personality variables. L is the ratio of the standard deviations of sibling 1 to sibling 2 for the environmental measures. The ideal value is to have both M and L as close to unity as possible. These statistics were computed only for those variables retained in the final regression equations for each of the kinship groups.

Results and Discussion

Due to the large number of analyses and results, each set of results are discussed immediately following presentation for clarity. A general summary and discussion will follow.

Stage 1: Descriptive Statistics

Group Averages

Means and standard deviations for the raw scale scores from MZ, DZ, and NT individuals are presented in Tables 4.1 to 4.8. Only a few statistically significant mean and variance differences were detected between MZ and DZ twins. The twin questionnaire item that asked siblings to list the number of ways they differ from their sibling showed that DZ twins reported significantly more within-pair differences than MZ twins. DZ's also have significantly larger scores than MZ's on five of the absolute SIDE scale scores. DZ twins report significantly greater differences in Antagonism, Caretaking, Peer College Orientation, Peer Delinquency, and Peer Popularity. DZs and NTs differ on Autonomy, and Change, on the PRF; Infrequency (L), Hypochondriasis, Schizoprhrenia, Hypomania, McAndrew Addiction Scale on the MMPI; Sibling Jealousy on the relatively scored SIDE; Sibling Jealousy, Maternal Affection, Maternal Control, Paternal Affection, Paternal Control, Peer College Orientation, Peer Delinquency, and Peer Popularity on absolutely scored SIDE scales; Intellectual-Cultural Orientation, and Organization on the FES; and finally, the number of separations, differences, and similarities listed. MZ and NT siblings were found to

Table 4.1

Means and F Ratios of Raw Personality Research Form Scale Scores for Monozygotic, Dizygotic, and NonTwin Individuals

PRF Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Abasement	6.32	6.43	5.88	1.52
Achievement	9.88	9.19	9.22	2.22
Affiliation	9.05	9.58	9.06	.79
Aggression	7.22	7.09	7.89	2.41
Autonomy	6.23[2,3]	6.48	7.74	8.84*
Change	7.98[2,3]	8.03	8.96	4.13*
Cognitive Structure	8.84	8.96	8.76	.11
Defendence	7.09	6.51	7.44	2.34
Dominance	8.20	7.89	9.02	2.35
Endurance	9.92	9.11	9.17	2.75
Exhibition	7.25	8.02	7.98	1.51
Harm Avoidance	10.15	9.93	9.05	2.49
Impulsivity	6.15	6.25	6.73	.99
Nurturance	10.16	10.68	9.98	1.54
Order	8.91	8.08	8.14	1.60
Play	8.21[3]	8.95	9.28	4.62*
Sentience	8.77	8.98	9.44	2.11
Social Recognition	8.39	8.35	7.68	2.08
Succorance	8.31	8.02	7.58	1.47
Understanding	8.29[3]	8.12	9.20	3.51*
Infrequency	.38[3]	.49	.74	4.00*
Desirability	11.66[3]	11.12	10.74	4.13*

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; $N_{MZ} = 176 - 178$; $N_{DZ} = 98$; $N_{NT} = 126$.

Table 4.2

Means and F Ratios of Raw Minnesota Multiphasic Personality Inventory Scale Scores for Monozygotic, Dizygotic, and NonTwin Individuals

MMPI Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Lie	3.92	3.50	3.59	1.38
Infrequency	5.21[2,3]	5.28	7.14	7.32*
Defensiveness	14.39	18.83	13.45	2.61
Hypochondriasis	7.02[2]	5.59	6.98	2.97
Depression	22.19	21.83	21.41	.72
Hysteria	21.94	21.03	21.50	1.06
Psychopathic Deviate	16.23[3]	17.26	18.23	5.59*
Masculinity-Femininity	34.53	35.43	35.35	1.01
Paranoia	11.05	10.53	11.22	1.08
Psychasthenia	14.99	14.21	15.59	.72
Schizophrenia	13.91[2]	12.84	15.89	3.15*
Hypomania	17.25[2,3]	17.43	19.79	10.06*
Social Introversion	27.85	26.60	26.74	.66
Anxiety	13.15	12.11	13.58	.71
Repression	16.74[3]	16.81	16.61	3.09*
Ego Strength	43.40	44.94	43.60	1.68
MacAndrew Addiction	20.08[2,3]	20.27	21.60	3.92*

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; $N_{MZ} = 159 - 160$; $N_{DZ} = 90$; $N_{NT} = 121$.

Table 4.3

Means and F Ratios for Raw Relative Sibling Inventory of Differential Experience Scale Scores for Monozygotic, Dizygotic, and NonTwin Individuals

SIDE Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Sibling Interaction				
Antagonism	2.89	2.83	2.95	.87
Caretaking	3.03	2.98	3.14	1.45
Jealousy	2.98[2,3]	2.93	3.18	4.44*
Closeness	3.05	3.00	2.99	.42
Parental Treatment				
Maternal Affection	2.93	3.01	2.97	.56
Maternal Control	2.99	3.08	3.09	.96
Paternal Affection	3.01	3.02	3.06	.33
Paternal Control	2.97	3.00	3.04	.29
Peer Characteristics				
College Orientation	3.05	3.07	3.17	1.28
Delinquency	3.04	2.94	3.07	.58
Popularity	3.06	3.03	3.12	.56

Note: [1] MZ mean significantly different from DZ mean at $p \le .05$; [2] DZ mean significantly different from NT mean at $p \le .05$; [3] MZ mean significantly different from NT mean at $p \le .05$; * $p \le .05$; $N_{MZ} = 106 - 174$; $N_{DZ} = 69 - 95$; $N_{NT} = 88 - 122$.

Table 4.4

Means and F Ratios Raw Absolute Sibling Inventory of Differential Experience Scale Scores for Monozygotic, Dizygotic, and NonTwin Individuals

SIDE Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Sibling Interaction				
Antagonism	.58[1]	.71	.63	3.37*
Caretaking	.67[1]	.77	.78	3.31*
Jealousy	.58[2,3]	.73	.72	4.54*
Closeness	.49	.63	.55	2.18
Parental Treatment				
Maternal Affection	.28[2,3]	.41	.49	9.35*
Maternal Control	.21[2,3]	.38	.45	8.55*
Paternal Affection	.23[2,3]	.28	.55	19.96*
Paternal Control	.20[2,3]	.29	.50	9.15*
Peer Characteristics				
College Orientation	.32[1,2]	.52	.62	18.94*
Delinquency	.37[1,2,3]	.53	.76	18.75*
Popularity	.41[1,2]	.69	.64	13.81*

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; $N_{MZ} = 106 - 174$; $N_{DZ} = 69 - 95$; $N_{NT} = 88 - 122$.

Table 4.5

Means and F Ratios of Raw Family Environment Scale Scores for Monozygotic, Dizygotic, and NonTwin Individuals

FES Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Relationship Dimension				
Cohesion	50.35[3]	45.93	44.91	3.45*
Expressiveness	47.26	44.66	45.99	.94
Conflict	48.73[3]	52.07	52.96	4.03*
Personal Growth				
Independence	48.83	46.88	49.15	.73
Achievement	50.15	49.34	48.71	.44
Intellectual-Cultural	48.02[2,3]	43.70	49.79	5.03*
Active-Recreational	48.85	50.00	50.13	.45
Moral-Religious	47.67	45.51	46.21	1.05
System Maintenance				
Organization	51.89[2,3]	48.26	47.71	4.72*
Control	48.01	49.87	49.34	.63

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; $N_{MZ} = 177$; $N_{DZ} = 97$; $N_{NT} = 128$.

Table 4.6

Means and F Ratios of Raw Classroom Environment Scale Scores for Monozygotic, Dizygotic, and NonTwin Individuals

Measure	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Relationship Dimension				
Involvement	52.96	51.30	53.44	1.18
Affiliation	49.65	49.23	50.41	.26
Teacher Support	49.52	47.83	50.29	1.42
Personal Growth				
Task Orientation	53.29	51.24	52.22	1.51
Competition	55.09	55.91	54.51	.52
System Maintenance				
Order & Organization	56.27	53.78	55.78	2.08
Rule Clarity	53.77	52.07	53.04	1.08
Teacher Control	54.92	55.22	55.34	.07
Innovation	49.53	49.59	50.83	.67

Note: N_{MZ} = 172; N_{DZ} = 91 - 92; N_{NT} = 125.

Table 4.7

Means and Standard Deviations of Raw Environmental Response Inventory Scale Scores for Monozygotic Individuals

Measure	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Pastoralism	75.09	72.36	75.71	1.73
Urbanism	61.60	63.31	62.73	.55
Environmental Adaption	70.24	71.17	70.90	.20
Stimulus Seeking	62.69	64.39	66.90	2.70
Environmental Trust	61.84	62.00	62.79	.30
Antiquarianism	64.14	65.26	66.76	1.14
Need Privacy	54.94	54.47	56.24	1.31
Mechanical Orientation	62.18	59.18	61.50	1.81
Communality	79.98	80.04	80.32	.08

Note: N_{MZ} = 128; N_{DZ} = 72; N_{NT} = 125.

Table 4.8

Means and F Ratios of Raw Twin Questionnaire Responses for Monozygotic, Dizygotic, and NonTwin Individuals

Measure	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Number of Illnesses	.99	1.37	1.14	2.07
Number of Separations	.24[2,3]	.42	1.23	35.44*
Number of Differences	7.99[1,2]	10.42	7.86	5.34*
Number of Similarities	6.42[2,3]	4.20	3.58	17.59*

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; $N_{MZ} = 178$; $N_{DZ} = 95 - 98$; $N_{NT} = 113 - 124$.

differ on a total of 24 of the scales. The MZ twins differed from the NT siblings on the same variables the DZs differed from the NTs. The DZs and NTs also differed on Understanding, Play, Infrequency, and Desirability from the PRF; Psychopathic Deviate, Repression, and the MacAndrew Addiction Scale from the MMPI; and Cohesion from the FES. On only one scale measure, absolutely scored Peer Delinquency from the SIDE, did all three kinships differ significantly from one another. It is also noteworthy that no kinship differences were detected on any of the CES scales, on just one ERI scale, and on only a few of the FES scales. The majority of the differences as a function of kinship are found on the absolute-scored SIDE scales and on the personality measures.

The FES and absolutely scored SIDE scales appear to give contradictory results. How is it that differences were detected on the family environment SIDE scales but not on the FES when both are purportedly measures of the family environment? This discrepancy may be attributable to the somewhat different content domains measured by both scales. Briefly, the SIDE scales are much more specific. For example, the SIDE directly assesses maternal and paternal affection. The FES, on the other hand, examines general family environment. Items on maternal and paternal affection are grouped together with other items and are only one component of "Family Organization" or "Family Cohesion".

In sum, there are only a few significant environmental differences between MZs and DZs. This result is important because it essentially lends support to one of the major assumptions of the twin design, that the environments of MZs are no more similar or different than the environments of DZs. Few significant differences were found between MZs and DZs, but a large number of significant differences were found between twins and NT siblings. These results suggest that the personalities and the environments of twins are not comparable to nontwin siblings. Twins appear to be a distinct group from nontwin siblings and the environments and personalities of twins are characteristic of their unique biological status. As such, the examinations of twins and nontwin siblings requires the separate analysis of each. Twins and nontwins siblings appear to be samples from different populations.

Sibling Differences

The means and standard deviations of the absolute intra-pair scale score differences from twin and sibling samples are presented in Tables 4.9 to 4.15. Perhaps the

Table 4.9

Means and F-Ratios of Raw Personality Research Form Scale Absolute Value Difference Scores Between Monozygotic, Dizygotic, and NonTwin Pairs

PRF Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Abasement	2.35	2.41	2.77	.83
Achievement	2.46	2.89	3.23	1.95
Affiliation	2.82	3.41	3.47	1.41
Aggression	2.78	3.12	3.07	.48
Autonomy	2.15[1,3]	3.12	3.69	9.25*
Change	2.17[1,3]	3.53	3.11	7.64*
Cognitive Structure	2.64	3.14	3.02	.85
Defendence	2.63	3.51	3.24	2.24
Dominance	3.71	3.29	3.74	.37
Endurance	2.77	3.16	3.71	2.33
Exhibition	3.00[1]	4.69	4.02	4.66*
Harm Avoidance	2.40[1,3]	3.33	3.77	5.40*
Impulsivity	2.63[1,3]	4.69	4.07	9.55*
Nurturance	2.45	2.51	2.69	.24
Order	3.78	4.49	4.94	1.93
Play	2.45	3.08	3.24	2.67
Sentience	1.99[1,3]	2.98	2.60	5.00*
Social Recognition	2.32[1,3]	3.18	3.87	9.31*
Succorance	2.93[1,3]	3.95	4.08	3.85*
Understanding	2.51[1]	3.63	3.16	3.67*
Infrequency	.43	.74	.82	2.78
Desirability	1.97[3]	2.41	3.03	5.41*

Note: [1] MZ mean significantly different from DZ mean at $p \le .05$; [2] DZ mean significantly different from NT mean at $p \le .05$; [3] MZ mean significantly different from NT mean at $p \le .05$; * $p \le .05$; $N_{MZ} = 87\text{-}88$; $N_{DZ} = 49$; $N_{NT} = 62$.

Table 4.10

Means and F-Ratios of Raw Minnesota Multiphasic Personality Inventory Scale Absolute Value Difference Scores Between Monozygotic, Dizygotic, and NonTwin Pairs

MMPI Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Lie	1.56[2,3]	1.80	2.42	5.40*
Infrequency	2.95[2,3]	2.96	4.75	4.52*
Defensiveness	3.60[1]	5.18	4.12	3.87*
Hypochondriasis	3.19[3]	4.34	4.92	4.36*
Depression	4.10	5.44	4.87	1.87
Hysteria	3.93[3]	5.44	5.08	3.38*
Psychopathic Deviate	3.70	4.73	4.95	1.99
Masculinity-Femininity	4.09	4.29	4.90	.93
Paranoia	2.60[3]	3.16	3.95	3.14*
Psychasthenia	5.66	6.64	7.03	.94
Schizophrenia	5.84[3]	7.38	9.63	4.89*
Hypomania	3.80[2,3]	4.82	6.47	8.14*
Social Introversion	7.15	9.47	9.32	2.51
Anxiety	6.08	7.42	7.93	1.63
Repression	3.58[1]	4.87	3.92	3.09*
Ego Strength	5.73	4.33	6.53	2.25
MacAndrew Addiction	3.63[2,3]	3.11	4.82	3.69*

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; N_{MZ} = 79 - 80 pairs; N_{DZ} = 45 pairs; N_{NT} = 60 pairs.

Table 4.11

Means and F-Ratios of Raw Absolute Sibling Inventory of Differential Experience Scale Absolute Value Scale Scores Between Monozygotic, Dizygotic, and NonTwin Pairs

SIDE Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Sibling Interaction				
Antagonism	.39	.34	.39	.20
Caretaking	.34	.38	.42	1.04
Jealousy	.38	.44	.48	.63
Closeness	.38	.37	.46	1.06
Parental Treatment				
Maternal Affection	.26	.37	.40	2.95
Maternal Control	.24	.30	.38	1.92
Paternal Affection	.22[3]	.28	.38	3.37*
Paternal Control	.18[3]	.23	.41	3.93*
Peer Characteristics				
College Orientation	.22[1,3]	.40	.41	6.16*
Delinquency	.33	.30	.47	2.61
Popularity	.29[3]	.37	.47	3.89*

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; ; * $p \leq .05$; N_{MZ} = 32 - 87 pairs; $_{DZ}$ = 27 - 46 pairs; N_{NT} = 32 - 56 pairs.

Table 4.12

Means and F-Ratios of Raw Family Environment Scale Absolute Value Difference Scores Between Monozygotic, Dizygotic, and NonTwin Pairs

FES Scale	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Relationship Dimension				
Cohesion	11.32[3]	16.42	18.32	4.56*
Expressiveness	13.48	13.33	12.76	.08
Conflict	8.74[2,3]	12.52	9.07	3.31*
Personal Growth				
Independence	12.06	12.56	14.48	.75
Achievement	9.30[2,3]	16.06	10.57	7.26*
Intellectual-Cultural	8.40[3]	12.67	11.8[illegible]	3.25*
Active-Recreational	9.49[1]	13.65	10.74	2.88*
Moral-Religious	7.69	6.35	9.45	1.78
System Maintenance				
Organization	8.71	12.38	8.82	2.45
Control	10.71	11.55	13.50	1.27

Note: [1] MZ mean significantly different from DZ mean at $p \leq .05$; [2] DZ mean significantly different from NT mean at $p \leq .05$; [3] MZ mean significantly different from NT mean at $p \leq .05$; * $p \leq .05$; N_{MZ} = 88 pairs; N_{DZ} = 47 - 48 pairs; N_{NT} = 62 pairs.

Table 4.13

Means and F-Ratios of Raw Classroom Environment Scale Absolute Value Difference Scores Between Monozygotic, Dizygotic, and NonTwin Pairs

Measure	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Relationship Dimension				
Involvement	10.11	9.27	10.18	.15
Affiliation	10.82	11.30	10.92	.03
Teacher Support	9.06	10.41	10.45	.47
Personal Growth				
Task Orientation	7.25	10.59	8.02	2.34
Competition	8.39	9.16	11.25	1.82
System Maintenance				
Order and Organization	7.95	9.86	9.38	1.19
Rule Clarity	8.00[3]	11.61	9.97	3.43*
Teacher Control	8.45	10.39	9.79	1.01
Innovation	8.73[3]	11.86	11.54	3.27*

Note: [1] MZ mean significantly different from DZ mean at $p \le .05$; [2] DZ mean significantly different from NT mean at $p \le .05$; [3] MZ mean significantly different from NT mean at $p \le .05$; * $p \le .05$; N_{MZ} = 84 pairs; N_{DZ} = 43 - 44 pairs; N_{NT} = 60 - 61 pairs.

Table 4.14

Means and F-Ratios of Raw Environmental Response Inventory Absolute Value Difference Scale Scores Between Monozygotic, Dizygotic, and NonTwin Pairs

Measure	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Pastoralism	7.73	12.72	10.62	2.72
Urbanism	9.55	9.94	11.26	.42
Environmental Adaption	8.30	9.39	10.00	.49
Stimulus Seeking	8.69	12.00	13.21	2.43
Environmental Trust	7.13	8.79	7.49	.46
Antiquarianism	8.98	12.25	12.36	1.86
Need Privacy	6.73	6.83	7.93	.66
Mechanical Orientation	8.05	10.86	9.48	1.55
Communality	5.66	5.92	7.77	2.45

Note: N_{MZ} = 64 pairs; N_{DZ} = 36 pairs; N_{NT} = 61 pairs.

Table 4.15

Means and F-Ratios for Raw Twin Questionnaire Absolute Value Response Differences Between Monozygotic, Dizygotic, and NonTwin Pairs

Measure	$Mean_{MZ}$	$Mean_{DZ}$	$Mean_{NT}$	F
Age	-	-	2.69	-
Number of Illnesses	1.23	1.55	1.47	.69
Number of Separations	0.00	0.00	0.00	0.00
Number of Differences	4.43	4.23	3.78	.37
Number of Similarities	3.44	3.26	2.57	1.15

Note: N_{MZ} = 87 - 89 pairs; N_{DZ} = 46 - 49 pairs; N_{NT} = 51 - 62 pairs.

most striking observations about these means are that they are all significantly non-zero within every kinship when tested with the goodness-of-fit t-test. These results clearly indicate that significant differences exist between twins and non-twin siblings. There was only one measure - number of separations - in which no twin or non-twin sibling differences were detected.

The magnitude of the differences between siblings appears to vary systematically by kinship. Typically, the differences are greatest for the NT siblings, followed by DZs and then MZs. This trend is expected, because MZ twins share the same genes and environments, DZs share the same environment but share only 50% of their genes on average and non-twin siblings share 50% of their genes, on average, and share the same general environment, but are separated by age.

A number of the observed kinship differences are statistically significant. DZ differences are significantly greater then MZ differences on Autonomy, Change, Exhibitionism, Harm Avoidance, Impulsivity, Sentience, Succorance, Understanding, and Desirability on the PRF. The DZ twins and NT siblings do not differ significantly on any PRF scale. Greater DZ and NT differences appear on the

MMPI, where the DZ differences are significantly lower on the Lie (L), Infrequency (F), Hypomania, and MacAndrew Addiction scales. MZ and DZ differences appear on the Defensiveness and (K) Repression scales. MZ and NT siblings differ significantly on the Lie (L), Defensiveness (K), Hysteria, Schizophrenia, Hypomania, Anxiety, and the MacAndrew addiction scales from the MMPI. MZs differed from DZs on the Peer College Orientation scale on the absolutely scored SIDE. On this measure, MZs and NTs differed on Paternal Affection, Paternal Control, Peer College Orientation, and the Peer Popularity Scales. On the FES, MZs and DZs only differ on one scale (Active-Recreational Orientation), whereas DZs and NTs differ on two (Conflict and Achievement Orientation), and MZs and NTs differ on four scales (Cohesion, Conflict, Intellectual-Cultural, and Achievement Orientation). On the CES, the only significant kinship differences were detected between MZs and NT siblings on the Rule Clarity and Innovation scales. Finally, no kinship differences were found for any scale on the ERI or the TQ. Although the general trend of NT > DZ > MZ exists for many of the sibling differences, there are some exceptions. For example, a significant mean difference exists between DZs and NTs on Achievement Orientation from the FES with a greater DZ twin difference. A possible explanation of this somewhat counterintuitive finding is that DZ twins express their individuality in this way.

Twin and Sibling Resemblance on Personality and Environmental Perceptions

Twin and sibling correlations are presented in Tables 4.16 to 4.23. MZ correlations on the PRF, MMPI, FES, and ERI are all statistically significant. DZ twin correlations on these measures are almost all lower than the MZ correlations, indicating the presence of genetic effects on most of these measures. NT sibling correlations are typically lower than the DZ correlations but the magnitude of the difference is small. It is interesting to note that although the DZ correlations fall in between the magnitude of the MZ and NT correlations, the DZ correlations are closer in size to the MZ correlations than to the NT correlations. This again indicates that all twins, MZs and DZs have an environment that is distinct from NT siblings. The pattern of twin and sibling correlations on the CES and relatively scored SIDE scales warrant special comment. With the CES, a seemingly uncharacteristically large number (5 of 9) of the DZ correlations exceed or are very similar in magnitude to the MZ correlations. This indicates that the majority of CES scales show very little or no genetic influence. Twin correlations on the relative SIDE scores are all negative and are for the most part statistically

Table 4.16

Pearson's Correlations for Normalized Age and Sex Corrected Personality Research Form Scale Scores of MZ, DZ, and Non-Twin Sibling Pairs

PRF Scale	MZ	DZ	NT
Abasement	.317*	.335*	-.065
Achievement	.530[1,*]	.170	.160[3]
Affiliation	.496*	.284*	.218
Aggression	.376*	.245	.147
Autonomy	.576*	.331*	.055[3]
Change	.594[1,*]	.133	.134[3]
Cognitive Structure	.318*	.272	.234
Defendence	.356*	.134	.185
Dominance	.355*	.477*	.231
Endurance	.399*	.149	.075[3]
Exhibition	.545[1,*]	.091	.163[3]
Harm Avoidance	.709[1,*]	.504	.427[3,*]
Impulsivity	.515[1,*]	.002	.034[3]
Nurturance	.502*	.320*	.339*
Order	.309*	.185	.042
Play	.518*	.299*	.138[3]
Sentience	.612[1,*]	.162	.353[3,*]
Social Recognition	.564*	.355*	-.083[3]
Succorance	.463*	.181	-.077[3]
Understanding	.567[1,*]	.121	.331*
Infrequency	.351[1,*]	.010[2]	.436*
Desirability	.531*	.494[2,*]	.0813

Note: * $p \le .05$, two-tailed; [1] r_{MZ} significant different from r_{DZ}, $p \le .05$, two-tailed; [2] r_{DZ} significant different from r_{NT}, $p \le .05$, two-tailed; [3] r_{MZ} significant different from r_{NT}, $p \le .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.17

Pearson's Correlations of Normalized Age and Sex Corrected Minnesota Multiphasic Personality Inventory Scale Scores for MZ, DZ, and Non-Twin Sibling Pairs

MMPI Scale	MZ	DZ	NT
Lie	.453*	.612^{2,*}	.044^{3}
Infrequency	.616^{1,*}	.250	.132^{3}
Defensiveness	.612^{1,*}	-.066	.278^{3,*}
Hypochondriasis	.672^{1,*}	.006	.002^{3}
Depression	.584^{1,*}	.041	.216^{3}
Hysteria	.528^{1,*}	-.010	.009^{3}
Psychopathic Deviate	.506^{1,*}	.171	.035^{3}
Masculinity-Femininity	.669^{1,*}	.311*	.242^{3}
Paranoia	.353*	.082	.071
Psychasthenia	.629^{1,*}	.283	-.216^{3}
Schizophrenia	.675^{1,*}	.226	.162
Hypomania	.502^{1,*}	.199	.236
Social Introversion	.625^{1,*}	.124	.162^{3}
Anxiety	.632^{1,*}	.354*	.231^{3}
Repression	.517^{1,*}	.027	.188^{3}
Ego Strength	.391*	.427*	.168
MacAndrew Addiction	.473*	.567^{2,*}	.206

Note: * $p \leq .05$, two-tailed; ^{1} r_{MZ} significant different from r_{DZ}, $p \leq .05$, two-tailed;_^{2} r_{DZ} significant different from r_{NT}, $p \leq .05$, two-tailed; ^{3} r_{MZ} significant different from r_{NT}, $p \leq .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.18

Pearson's Correlations of Normalized Age and Sex Corrected Relative Sibling Inventory of Differential Experience Scale Scores for MZ, DZ, and Non-Twin Sibling Pairs

SIDE Scale	MZ	DZ	NT
Sibling Interaction			
Antagonism	-.247*	-.373[2,*]	.005
Caretaking	-.431*	-.312*	-.463*
Jealousy	-.249*	-.351*	-.468*
Closeness	-.245*	-.100	-.299*
Parental Treatment			
Maternal Affection	-.243*	-.098	-.372*
Maternal Control	-.203	-.411*	-.555[3,*]
Paternal Affection	-.113	-.181	-.461[3,*]
Paternal Control	-.336[1,*]	-.759*	-.549*
Peer Characteristics			
College Orientation	-.236*	-.273	-.422*
Delinquency	-.378*	-.406*	-.574*
Popularity	-.323*	-.298*	-.442*

Note: * $p \leq .05$, two-tailed; [1] r_{MZ} significant different from r_{DZ}, $p \leq .05$, two-tailed;_[2] r_{DZ} significant different from r_{NT}, $p \leq .05$, two-tailed; [3] r_{MZ} significant different from r_{NT}, $p \leq .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.19

Pearson's Correlations of Normalized Age and Sex Corrected Absolute Sibling Inventory of Differential Experience Scale Scores for MZ, DZ, and Non-Twin Sibling Pairs

SIDE Scale	MZ	DZ	NT
Sibling Interaction			
Antagonism	.279*	.471*	.157
Caretaking	.423*	.307*	-.131
Jealousy	.200	.298*	.260
Closeness	.301*	.377*	.348*
Parental Treatment			
Maternal Affection	.427*	.163	.287*
Maternal Control	.420*	.622*	.404*
Paternal Affection	.437*	.340*	.345*
Paternal Control	.633*	.732*	.390*
Peer Characteristics			
College Orientation	.571^{1,*}	.153	.138^{3}
Delinquency	.467*	.399*	.341*
Popularity	.530*	.412*	.116^{3}

Note: * $p \leq .05$, two-tailed; ^{1} r_{MZ} significant different from r_{DZ}, $p \leq .05$, two-tailed; ^{2} r_{DZ} significant different from r_{NT}, $p \leq .05$, two-tailed; ^{3} r_{MZ} significant different from r_{NT}, $p \leq .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.20

Pearson Correlations of Normalized Age and Sex Corrected Family Environment Scale Scores for MZ, DZ, and Non-Twin Sibling Pairs

FES Scale	MZ	DZ	NT
Relationship Dimension			
Cohesion	$.583^{1,*}$	.272	$.261^{3,*}$
Expressiveness	$.381^{*}$	.189	$.422^{*}$
Conflict	$.609^{*}$	$.459^{*}$	$.510^{*}$
Personal Growth			
Independence	$.298^{*}$	$.542^{2,*}$	-.005
Achievement	$.470^{1,*}$	$.062^{2}$	$.420^{*}$
Intellectual-Cultural	$.554^{*}$	$.468^{*}$	$.356^{*}$
Active-Recreational	$.478^{*}$	.207	$.368^{*}$
Moral-Religious	$.616^{*}$	$.565^{*}$	$.510^{*}$
System Maintenance			
Organization	$.389^{*}$	$.336^{*}$	$.572^{*}$
Control	$.429^{*}$	$.413^{*}$	$.299^{*}$

Note: * $p \leq .05$, two-tailed; ^{1} r_{MZ} significant different from r_{DZ}, $p \leq .05$, two-tailed; ^{2} r_{DZ} significant different from r_{NT}, $p \leq .05$, two-tailed; ^{3} r_{MZ} significant different from r_{NT}, $p \leq .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.21

Pearson Correlations of Normalized Age and Sex Corrected Classroom Environment Scale Scores for MZ, DZ, and Non-Twin Sibling Pairs

Measure	MZ	DZ	NT
Relationship Dimension			
Involvement	.179	.367*	.117
Affiliation	.277*	.289	.259*
Teacher Support	.184	.213	.141
Personal Growth			
Task Orientation	.255*	.067	.231
Competition	.217*	.242	-.051
System Maintenance			
Order and Organization	.367*	.347*	.120
Rule Clarity	.231*	.048	.146
Teacher Control	.311*	.021	.108
Innovation	.277*	.141	.116

Note: * $p \leq .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.22

Pearson Correlation of Normalized Age and Sex Corrected Environmental Response Inventory Scale Scores for MZ, DZ, and Non-Twin Sibling Pairs

Measure	MZ	DZ	NT
Pastoralism	.471*	.198	.310*
Urbanism	.405*	-.024	.173
Environmental Adaption	.339*	.168	.298*
Stimulus Seeking	.606*	.125	.281*
Environmental Trust	.306*	.347*	.501*
Antiquarianism	.447*	.079	.060
Need Privacy	.433*	.307	.241
Mechanical Orientation	.542*	.184	.354*
Communality	.331*	.115	.099

Note: * $p \leq .05$, two-tailed; Sample sizes as Tables 4.25 to 4.45.

Table 4.23

Pearson Correlation of Normalized Age and Sex Corrected Twin Questionnaire Responses for MZ, DZ, and Non-Twin Sibling Pairs

Measure	MZ	DZ	NT
Number of Illnesses	-.024	.018	-.149
Number of Separations	1.000*	1.000*	1.000*
Number of Differences	.562*	.534[2,*]	.121[3,*]
Number of Similarities	.516*	.307*	.410*

* $p \leq .05$, two-tailed;

[1] r_{MZ} significant different from r_{DZ}, $p \leq .05$, two-tailed;

[2] r_{DZ} significant different from r_{NT}, $p \leq .05$, two-tailed;

[3] r_{MZ} significant different from r_{NT}, $p \leq .05$, two-tailed;

Sample sizes as Tables 4.25 to 4.45.

significant, indicating that siblings agree about the direction and the amount of differential experience. With this inventory, a systematic pattern is present with the NT sibling correlations being the largest, followed next in size by the DZ correlations, followed in magnitude by the MZ correlations. This pattern clearly shows that NT siblings perceive more differential experience than DZs who in turn perceive more differential experience than MZs.

The MZ correlations on the absolutely scored SIDE scales are larger than the DZ correlations for Sibling Caretaking, Maternal Affection, Paternal Affection, Peer College Orientation, Peer Delinquency, and Peer Popularity. All scales of the FES, with the exception of Independence show larger MZ than DZ correlations. These results clearly indicate a presence of a genetic component to these so-called "environmental" measures. The only scale that appears to be a wholly exogenous measure of the environment is the CES. The others show substantial genetic influences. MZ correlations are greatest on the number of similarities and the number of differences cited.

A closer examination of these twin and sibling correlations by measure reveals that the MZ MMPI correlations are almost all (76% of the scales) greater than twice the size of the DZ correlations. This indicates that liability to psychopathology as measured by these scales has a nonadditive genetic etiology as well. The four exceptions to this finding are with the Lie, Anxiety, Ego Strength, and MacAndrew Addiction Scales. The genetic variance in Ego Strength and Anxiety appears to be purely additive in nature whereas no genetic variance is indicated for the Lie and MacAndrew scales. It is noteworthy that with no other scale used in this study is this pattern so apparent. A number of the PRF scales (40%) also show MZ correlations more than twice the magnitude of the DZ correlation. However, because relatively few of the normal personality traits appear to be influenced by nonadditive genetic variance, one can speculate that a fundamental difference between normal personality development and liability to personality disorder is the presence of nonadditive genetic effects. However, this remains to be tested.

Relationship of Gender and Age to Personality and Environmental Perceptions

The correlations between gender and age with each of the independent and dependent variables are presented in Tables 4.24 and 4.25. A number of significant correlations were detected between gender and the measures. However, for

Table 4.24

Correlations Between Personality and Environmental Measures with Gender for the Total Sample of Twin and Sibling Individuals

Measure	r	N
Personality Research Form		
Achievement	.125	400
Autonomy	.205	400
Cognitive Structure	-.127	400
Dominance	.122	401
Endurance	.113	401
Exhibition	.105	402
Harm Avoidance	-.375	400
Nurturance	-.120	402
Order	-.204	402
Succorance	-.197	401
Understanding	.107	401
Minnesota Multiphasic Personality Inventory		
Lie	.102	371
Hypochondriasis	-.122	371
Depression	-.154	371
Masculinity-Femininity	-.574	371
Social Introversion	-.120	371
Repression	-.189	371
Ego Strength	.168	371
Family Environment Scale		
Control	-.105	399

Classroom Environment Scale		
Involvement	-.125	389
Task Orientation	-.108	389
Environmental Response Inventory		
Stimulus Seeking	.175	325
Environmental Trust	.149	325
Need Privacy	-.115	325
Mechanical Orientation	.357	325

Note: All correlations in this table are significant at $p \leq .05$, two-tailed. No significant correlations were detected for any of the absolutely scored Sibling Inventory of Differential Experience Scales; or any of the additional Twin Questionnaire items.

Table 4.25

Correlations Between Personality and Environmental Measures with Age for the Total Sample of Twin and Sibling Individuals

Measure	r	N
Personality Research Form		
Abasement	.105	399
Affiliation	-.183	399
Aggression	-.174	399
Change	-.239	399
Cognitive Structure	.168	399
Defendence	-.122	399
Dominance	-.141	399
Exhibition	-.171	400
Harm Avoidance	.291	398
Impulsivity	-.144	400
Order	.181	400
Play	-.251	400
Social Recognition	-.257	400
Minnesota Multiphasic Personality Inventory		
Lie	.208	368
Infrequency	-.131	367
Defensiveness	.131	368
Depression	.114	368
Hysteria	.150	368
Schizophrenia	-.142	368
Hypomania	-.231	368
Social Introversion	.102	368
Anxiety	-.108	368
Repression	.235	368
MacAndrew Addiction	.141	368

Sibling Inventory of Differential Experience		
Closeness	.116	379
Parental Treatment		
Maternal Control	-.130	294
Orientaticn Toward College	-.175	261
Family Environment Scale		
Achievement	-.157	398
Intellectual-Cultural	-.258	398
Active-Recreational	-.146	398
Classroom Environment Scale		
Involvement	.106	387
Order and Organization	.115	387
Teacher Control	.115	387
Environmental Response Inventory		
Urbanism	-.182	323
Stimulus Seeking	-.254	323
Additional Twin Questionnaire Items		
Number of Illnesses	.128	392
Number of Separations		
Number of Differences	.151	385
Number of Similarities	.158	383

Note: All correlations in this table are significant at $p \leq .05$, two-tailed.

the most part the correlations were low (median = .125) and account for very little of the variance (.06% to 33%). Many of the correlations are predictable from the traditional interpretation of sex differences. For example, females tend to be more Harm Avoidant, higher in Succorance, and more Teacher Oriented. Males tend to be greater in Sensation Seeking, and have a greater tendency to Lie on the MMPI. Age correlations with each of the measures are also small (median = .150) and again many are predictable. For example, as age increases, Sensation Seeking tendencies decrease and the number of illnesses reported increases.

Stage 2: Quantitative Genetic Analyses

Model fitting results are presented in Tables 4.26 to 4.31. The full ACE model was fitted to all personality and environmental scales. This model was found to fit the data satisfactorily. However, a number of models showed zero shared environmental effects and the ratio of the MZ correlation to the DZ correlation was greater than 2.0. This was the case for the majority of the personality measures. With the PRF, the exceptions were Abasement, Affiliation, Aggression, Autonomy, Cognitive Structure, Dominance, Harm Avoidance, Nurturance, Order, Play, Social Recognition, and Desirability scales. Only four MMPI scales

Table 4.26

Model Fitting Results for Full Quantitative Genetic Models (ACE vs ADE) on the Personality Research Form Scales

	Fit in chi-square units	
Scale	ACE[1,5]	ADE[2,5]
Abasement	.01[3,4]	-
Achievement	.85	.00[3,4]
Affiliation	.01[3,4]	-
Aggression	.00[3,4]	-
Autonomy	.32[3,4]	-
Change	1.64	.07[3,4]
Cognitive Structure	.01[3,4]	-
Defendence	.34	.01[3,4]
Dominance	1.29[3,4]	-
Endurance	.33	.01[3,4]
Exhibition	1.42	.08[3,4]
Harm Avoidance	.01[3,4]	-
Impulsivity	3.94	1.29[3,4]
Nurturance	.01[3,4]	-
Order	.03[3,4]	-
Play	.03[3,4]	-
Sentience	1.60	.01[3,4]
Social Recognition	.01[3,4]	-
Succorance	3.09	.93[3,4]
Understanding	1.64	.07[3,4]
Infrequency	2.12	.80[3,4]
Desirability	.01	.00[3,4]

Note: [1] A = additive genetic factors, C = shared environmental; factors, E = nonshared environmental factors; [2] A = additive genetic factors, D = Nonadditive genetic factors, E = nonshared environmental factors; [3] Best fitting by chi-square; [4] Best fitting by Akaike's Information Criterion (1970, 1987); [5] df=3.

Table 4.27

Model Fitting Results for Full Quantitative Genetic Models (ACE vs ADE) on the MMPI Scales

Scale	Fit in chi-square units	
	ACE[1,5]	ADE[2,5]
Lie	.22[3,4]	-
Infrequency	.24	.22[3,4]
Defensiveness	6.89	3.79[3,4]
Hypochondriasis	6.14	2.74[3,4]
Depression	6.21	2.13[3,4]
Hysteria	6.68	3.14[3,4]
Psychopathic Deviate	.31	.00[3,4]
Masculinity-Femininity	.62	.04[3,4]
Paranoia	.57	.01[3,4]
Psychasthenia	.17	.00[3,4]
Schizophrenia	1.60	.00[3,4]
Hypomania	1.90	.21[3,4]
Social Introversion	1.82	.03[3,4]
Anxiety	.02	.01[3,4]
Repression	1.76	.36[3,4]
Ego Strength	.00[3,4]	-
MacAndrew Addiction	.68[3,4]	-

Note: [1] A = additive genetic factors, C = shared environmental; factors, E = nonshared environmental factors; [2] A = additive genetic factors, D = Nonadditive genetic factors, E = nonshared environmental factors; [3] Best fitting by chi-square; [4] Best fitting by Akaike's Information Criterion (1970, 1987); [5] df=3

Table 4.28

Model Fitting Results for Full Quantitative Genetic Models (ACE vs ADE) on the Absolute SIDE Scales

	Fit in chi-square units	
Scale	ACE[1,5]	ADE[2,5]
Sibling Interaction		
Antagonism	1.67[3,4]	-
Caretaking	.00[3,4]	-
Jealousy	.34[3,4]	-
Closeness	.24[3,4]	-
Parental Treatment		
Maternal Affection	.12[3,4]	2.32
Maternal Control	2.82[3,4]	-
Paternal Affection	.00[3,4]	-
Paternal Control	1.44[3,4]	-
Peer Characteristics		
College Orientation	.89[3,4]	8.88*
Delinquency	.00[3,4]	-
Popularity	.00[3,4]	-

Note: [1] A = additive genetic factors, C = shared environmental; factors, E = nonshared environmental factors; [2] A = additive genetic factors, D = Nonadditive genetic factors, E = nonshared environmental factors; [3] Best fitting by chi-square; [4] Best fitting by Akaike's Information Criterion (1970, 1987); [5] df=3; * significant at $p \leq .05$.

Table 4.29

Model Fitting Results for Full Quantitative Genetic Models (ACE vs ADE) on the Family Environment Scale s

Scale	Fit in chi-square units	
	ACE[1,5]	ADE[2,5]
Relationship Dimension		
Cohesion	.10	.03[3,4]
Expressiveness	.03[3,4]	-
Conflict	.03[3,4]	-
Personal Growth		
Independence	.03[3,4]	-
Achievement	1.99	.31[3,4]
Intellectual-Cultural	.03[3,4]	-
Active-Recreational	.03[3,4]	-
Moral-Religious	.03[3,4]	-
System Maintenance		
Organization	.03[3,4]	-
Control	.04[3,4]	-

Note: [1] A = additive genetic factors, C = shared environmental; factors, E = nonshared environmental factors; [2] A = additive genetic factors, D = Nonadditive genetic factors, E = nonshared environmental factors; [3] Best fitting by chi-square; [4] Best fitting by Akaike's Information Criterion (1970, 1987); [5] df=3.

Table 4.30

Model Fitting Results for Full Quantitative Genetic Models (ACE vs ADE) on the Classroom Environment Scales

Scale	Fit in chi-square units	
	ACE[1,5]	ADE[2,5]
Relationship Dimension		
Involvement	1.37[3,4]	-
Affiliation	.11[3,4]	-
Teacher Support	.26[3,4]	-
Personal Growth		
Task Orientation	.42	.11[3,4]
Competition	.13[3,4]	-
System Maintenance		
Order and Organization	.29[3,4]	-
Rule Clarity	.23	.11[3,4]
Teacher Control	.52	.15[3,4]
Innovation	.11[3,4]	-

Note: [1] A = additive genetic factors, C = shared environmental; factors, E = nonshared environmental factors; [2] A = additive genetic factors, D = Nonadditive genetic factors, E = nonshared environmental factors; [3] Best fitting by chi-square; [4] Best fitting by Akaike's Information Criterion (1970, 1987); [5] df=3.

Table 4.31

Model Fitting Results for Full Quantitative Genetic Models (ACE vs ADE) on the Environmental Response Inventory Scales

	Fit in chi-square units	
Scale	ACE[1,5]	ADE[2,5]
Pastoralism	.01	.00[3,4]
Urbanism	1.29	.25[3,4]
Environmental Adaption	.00[3,4]	-
Stimulus Seeking	.69	.00[3,4]
Environmental Trust	.00[3,4]	-
Antiquarianism	1.70	.23[3,4]
Need Privacy	.00[3,4]	-
Mechanical Orientation	.38	.00[3,4]
Communality	.29	.00[3,4]

Note: [1] A = additive genetic factors, C = shared environmental; factors, E = nonshared environmental factors; [2] A = additive genetic factors, D = Nonadditive genetic factors, E = nonshared environmental factors; [3] Best fitting by chi-square; [4] Best fitting by Akaike's Information Criterion (1970, 1987); [5] df=3.

- Lie, Ego Strength, Repression, and the MacAndrew Addiction Scale - show no indication of nonadditive genetic effects. Most of the environmental measures show little evidence of a nonadditive effect. The exceptions are Maternal Affection and Peer College Orientation scales on the absolutely scored SIDE scales; Cohesion, Independence, and Achievement scales on the FES; and Task Orientation, Rule Clarity, and Teacher Control scales on the CES. Most of the ERI scales show evidence of nonadditive genetic variance. The exceptions are Environmental Adaption, Environmental Trust, and the Need for Privacy scales.

On the scales where the presence of nonadditive genetic variance is indicated, the ADE model was also fitted. The full ADE model provided a superior fit by chi-square and Aikaike's Information Criterion in all cases. For this reason, the model that produces the smallest value of chi-square, AIC, and provides the most substantively parsimonious explanation of the data is retained as the best-fitting. The ADE model provide the best fit by these statistical and substantive criteria in all cases except the Maternal Affection and Peer College Orientation scales on the absolutely scored SIDE scales. Here, a model allowing for nonadditive genetic effects attributable to genetic dominance does not fit. The source of the nonadditive genetic variance may be attributable to epistatic interactions (interactions between allelles at other loci). Unfortunately, these effects are presently not testable with model fitting methods. This is because although MZ twins share all of their genes, they would share the same deviations. This is not the case with DZ twins which only share half of their genes and because epistatic effects are not inherited from parents, no proportion of shared genetic effects can be deduced and included in a model.

The results of the reduced model fitting are presented in Tables 4.32 to 4.37. Removal of additive genetic factors (Model 2, the CE or DE only model) produced poor fits for a number of the personality scales. On the PRF, additive genetic influences are shown to be significant on Achievement, Autonomy, Change, Exhibition, Harm Avoidance, Impulsivity, Sentience, Understanding, and Infrequency. On the MMPI, the removal of additive genetic effects produces significantly poor fits in all scales with the exception of the Lie, Infrequency (F), Paranoia, Ego Strength, and MacAndrew Addiction Scales. No significant additive genetic effects were found for any of the absolutely scored SIDE scales with the single exception of the Peer College Orientation scale. Significant additive genetic effects were found on the Cohesion and Achievement scales of the

Table 4.32

Model Fitting for Estimates of Genetic and Environmental Influences on Personality Research Form Scales

Scale[1]	Overall model fit in chi-square units			
	Full *(df=3)*	CE or DE *(df=4)*	AE *(df=4)*	E *(df=5)*
Abasement	.01	.02[2]	1.14	15.84*
Achievement	.00	7.23	.85[2]	29.64*
Affiliation	.01	1.80	.02[2]	21.30*
Aggression	.00	.67	.06[2]	12.25*
Autonomy	.32	7.21	.32[2]	37.76*
Change	.07	10.51*	1.64[2]	35.48*
Cognitive Structure	.01	.37[2]	.13	10.27
Defendence	.01	2.66	.34[2]	12.98*
Dominance	1.29	1.29[2]	5.77	22.31*
Endurance	.01	3.06	.33[2]	15.59*
Exhibition	.08	8.15	1.42[2]	28.19*
Harm Avoidance	.01	8.11	.01[2]	54.04*
Impulsivity	1.29	11.49*	3.94[2]	25.40*
Nurturance	.01	1.92	.16[2]	28.85*
Order	.03	.83	.03[2]	7.14
Play	.03	3.29	.03[2]	27.50*
Sentience	.01	12.37*	1.60[2]	47.21*
Social Recognition	.01	1.17	.65[2]	31.90*
Succorance	.09	9.34	3.09[2]	21.91*
Understanding	.07	10.42*	1.64[2]	35.16*
Infrequency	.80	5.40	2.12[2]	11.85*
Desirability	.01	.14[2]	3.36	43.44*

Note: [1] Scale names in bold-face type denote that the full model fitted was the ADE model; [2] Overall best-fitting and most parsimonious model; * significant at $p \leq .05$.

Table 4.33

Model Fitting for Estimates of Genetic and Environmental Influences on MMPI Scales

Scale	Overall model fit in chi-square units			
	Full[1] (*df=3*)	CE or DE (*df=4*)	AE (*df=4*)	E (*df=5*)
Lie	.22	.22[2]	4.77	32.06*
Infrequency	.22	2.25	.24[2]	16.55*
Defensiveness	3.79	20.81*	6.89[2]	41.03*
Hypochondriasis	2.74	24.21*	6.14[2]	52.20*
Depression	2.13	18.05*	6.21[2]	36.09*
Hysteria	3.14	14.60*	6.68[2]	24.90*
Psychopathic Deviate	.00	5.12	.31[2]	27.40*
Masculinity-Femininity	.64	5.79	.62[2]	25.93*
Paranoia	.01	3.46	.57[2]	14.32*
Psychasthenia	.00	8.81	.17[2]	47.68*
Schizophrenia	.00	14.47*	1.60[2]	48.96*
Hypomania	.21	9.07	1.90[2]	27.59*
Social Introversion	.03	13.61*	1.82[2]	44.53*
Anxiety	.01	7.27	.02[2]	49.03*
Repression	.36	6.38	1.76[2]	17.93*
Ego Strength	.00	.68[2]	.77	27.07*
MacAndrew Addiction	.68	.68[2]	7.95	43.24*

Note: [1] Scale names in bold-face type denote that the full model fitted was the ADE model; [2] Overall best-fitting and most parsimonious model; * significant at $p \leq .05$.

Table 4.34

Model Fitting for Estimates of Genetic and Environmental Influences on Absolute SIDE Scales

Scale	Overall model fit in chi-square units			
	Full[1] *(df=3)*	CE *(df=4)*	AE *(df=4)*	E *(df=5)*
Sibling Interaction				
Antagonism	1.67	1.67[2]	5.68	18.24*
Caretaking	.00	.61	.46[2]	21.42*
Jealousy	.34	.34[2]	1.73	7.68*
Closeness	.24	.24[2]	2.50	15.07*
Parental Treatment				
Maternal Affection	.12	2.80	.12[2]	18.53*
Maternal Control	2.82	2.82[2]	11.15*	38.70*
Paternal Affection	.00	.45[2]	.76	23.74*
Paternal Control	1.44	1.44[2]	16.03*	78.55*
Characteristics				
College Orientation	.89	8.57	.89[2]	35.00*
Delinquency	.00	.25[2]	1.50	28.95*
Popularity	.00	.84[2]	1.25	36.67*

Note: [1] Scale names in bold-face type denote that the full model fitted was the ADE model; [2] Overall best-fitting and most parsimonious model; * significant at $p \leq .05$.

Table 4.35

Model Fitting for Estimates of Genetic and Environmental Influences on Family Environment Scales

Scale	Overall model fit in chi-square units			
	Full[1] (*df=3*)	CE or DE (*df=4*)	AE (*df=4*)	E (*df=5*)
Relationship Dimension				
Cohesion	.03	5.96	.10[2]	41.12*
Expressiveness	.03	1.09	.07[2]	18.43*
Conflict	.03	1.94	1.20[2]	56.11*
Personal Growth				
Independence	.03	1.26	.30[2]	56.40*
Achievement	.31	8.65	1.99[2]	26.04*
Intellectual-Cultural	.03	1.15	1.47[2]	51.07*
Active-Recreational	.03	3.12	.05[2]	35.96*
Moral-Religious	.03	.09[2]	5.75	75.04*
System Maintenance				
Organization	.03	.19[2]	1.70	35.69*
Control	.04	.05[2]	2.24	33.94*

Note: [1] Scale names in bold-face type denote that the full model fitted was the ADE model; [2] Overall best-fitting and most parsimonious model; * significant at $p \leq .05$.

Table 4.36

Model Fitting for Estimates of Genetic and Environmental Influences on the Classroom Environment Scales

Scale	Overall model fit in chi-square units			
	Full[1] *(df=3)*	CE or DE *(df=4)*	AE *(df=4)*	E *(df=5)*
Relationship Dimension				
Involvement	1.03	1.37[2]	4.00	12.23*
Affiliation	.11	.32[2]	.35	11.04
Teacher Support	.26	.26[2]	1.50	8.79
Personal Growth				
Task Orientation	.11	2.24	.42[2]	10.55
Competition	.13	.13[2]	1.02	9.68
System Maintenance				
Order and Organization	.29	.29[2]	2.36	15.34*
Rule Clarity	.11	.87	.23[2]	3.96
Teacher Control	.15	1.97	.52[2]	7.57
Innovation	.11	.28	.25[2]	7.84

Note: [1] Scale names in bold-face type denote that the full model fitted was the ADE model; [2] Overall best-fitting and most parsimonious model; * significant at $p \leq .05$.

Table 4.37

Model Fitting for Estimates of Genetic and Environmental Influences on Environmental Response Inventory Scales

Scale	Overall model fit in chi-square units			
	Full[1] *(df=3)*	CE or DE *(df=4)*	AE *(df=4)*	E *(df=5)*
Pastoralism	.00	3.51	.01[2]	21.14*
Urbanism	.25	4.80	1.29[2]	13.47*
Environmental Adaption	.00	.33[2]	.45	15.24*
Stimulus Seeking	.00	7.77	.69[2]	30.73*
Environmental Trust	.00	.01[2]	.98	12.58*
Antiquarianism	.23	7.69	1.70[2]	22.04*
Need Privacy	.00	.37[2]	.41	15.58*
Mechanical Orientation	.00	3.72	.38[2]	17.17*
Communality	.00	1.86	.29[2]	8.28

Note: [1] Scale names in bold-face type denote that the full model fitted was the ADE model; [2] Overall best-fitting and most parsimonious model; * significant at $p \leq .05$.

FES, with none on the CES. Three ERI scales - Urbanism, Stimulus Seeking, and Antiquarianism - also have significant additive genetic effects.

Removal of the shared environmental component or nonadditive genetic variance (Model 3, the AE only model) produced unacceptably poor fits in only a few measures. They are Dominance from the PRF; the Lie, Depression, and MacAndrew addiction scales from the MMPI; the Sibling Antagonism, Maternal Control, and the Paternal Control scales from the absolutely scored SIDE; and finally, the Moral-Religious Emphasis scale from the FES. Without exception, Model 4, which allows for nonshared effects alone, cannot adequately account for the data in any of the measures.

This comparison of models to one another indicates which one best explains the data. There are a number of criteria one can use to select a best-fitting model. First and foremost, the present study retained the model in which the overall model fit as measured by chi-square was lowest. In scales where competing models have the same chi-square value, or the difference between chi-square values was nonsignificant, the "Law of Parsimony" and the Aikaike's Information Criterion (AIC) were used to select the best-fitting model. In these cases, the model that had the fewest parameters (that is, could explain the data with the fewest number of parameters) and the lowest value of AIC was chosen.

The model specifying only additive genetic effects and nonshared environmental effects provided the best fit for all the PRF scales except for Abasement, Dominance, and Desirability. For these three scales, a completely environmental model was sufficient to explain the data. The AE model also provided the best explanation for the data on all MMPI scales with the exception of the Lie, Ego Strength, and MacAndrew Addiction scales. Once again, a completely environmental model provided the best fit to the data for these scales. The greatest proportion of the absolutely scored SIDE scale variance could be explained by a completely environmental model. Three SIDE scales were best explained by a model specifying additive genetic and nonshared environmental factors. These are Sibling Caretaking, Differential Maternal Affection, and Peer College Orientation. The AE model again provides the best fit for most of the FES scales. The exceptions are Moral-Religious Emphasis, Organization, and Control which are best explained by the CE model. The Involvement, Affiliation, Teacher Support, Competition, and Order and Organization scales from the CES are best explained by completely environmental factors. Additive genetic and nonshared environmental factors explain the variance on the Task Orientation, Rule Clarity, Teacher Control, and Innovation scales of the CES. All but three scales of the ERI are best explained by the AE model. The CE model provides the overall best fit for the Environmental Adaption, Environmental Trust, and Need for Privacy scales.

These model-fitting results clearly show that nonshared environmental effects are present on every scale used in the present study. When coupled with additive genetic effects, the two components can account for all of the variance in most of the personality and liability to personality disorder variables. Such a result suggests that the spectrum of behaviours comprising normal personality and liability to personality disorder are little influenced by shared environmental factors. In a number of cases the "environmental" measures appear to have significant additive genetic influences. However, the genetic effects are substantially smaller on these measures than they are on the personality measures. Finally, although for most of the personality measures and some of the environmental measures an overall model allowing for nonadditive genetic effects was specified, none of these variables was subsequently shown in the reduced model-fitting to have any significant nonadditive effects attributable to genetic dominance. These effects are present but they are of negligible consequence.

Heritability and environmentality estimates based on the best-fitting models are presented in Tables 4.38 to 4.43. These estimates give an indication of the effective magnitude of each of the effects. The median heritability of the PRF scales is .438. This result is in line with other measures of normal personality. This is the first time the heritability and environmentality estimates have been presented for this scale. Recall that most of the research has centred around neuroticism and extraversion, with little research with broader measures of personality. As typical of other studies, the nonshared environmental factors account for as much or more of the variance than the additive genetic factors, and shared environmental effects are small or nonexistent. Furthermore, little nonadditive genetic influence attributable to genetic dominance was found for any of the scales.

Interestingly, a few of the PRF scales show little effective additive genetic influence. These are Abasement, Dominance, and Desirability. The additive genetic influence

Table 4.38

Personality Research Form Heritability and Environmentality Estimates

Scale	h^2_N	d^2	c^2	e^2
Abasement	.000	.000	.332	.669
Achievement	.527	.000	.000	.473
Affiliation	.438	.000	.000	.563
Aggression	.338	.000	.000	.663
Autonomy	.569	.000	.000	.432
Change	.569	.000	.000	.430
Cognitive Structure	.000	.000	.265	.734
Defendence	.364	.000	.000	.637
Dominance	.000	.000	.378	.621
Endurance	.396	.000	.000	.621
Exhibition	.516	.000	.000	.484
Harm Avoidance	.651	.000	.000	.348
Impulsivity	.371	.000	.000	.513
Nurturance	.497	.000	.000	.503
Order	.262	.000	.000	.738
Play	.493	.000	.000	.507
Social Recognition	.599	.000	.000	.402
Sentience	.513	.000	.000	.487
Succorance	.458	.000	.000	.542
Understanding	.567	.000	.000	.433
Infrequency	.310	.000	.000	.689
Desirability	.000	.000	.523	.477

Table 4.39

MMPI Heritability and Environmentality Estimates

Scale	h^2_N	d^2	c^2	e^2
Lie	.000	.000	.460	.540
Infrequency	.406	.000	.000	.594
Defensiveness	.599	.000	.000	.401
Hypochondriasis	.645	.000	.000	.354
Depression	.572	.000	.000	.428
Hysteria	.473	.000	.000	.526
Psychopathic Deviate	.510	.000	.000	.490
Masculinity-Femininity	.501	.000	.000	.598
Paranoia	.384	.000	.000	.616
Psychasthenia	.635	.000	.000	.365
Schizophrenia	.651	.000	.000	.349
Hypomania	.517	.000	.000	.483
Social Introversion	.627	.000	.000	.372
Anxiety	.637	.000	.000	.362
Repression	.424	.000	.000	.576
Ego Strength	.000	.000	.423	.578
MacAndrew Addiction	.000	.000	.521	.479

Table 4.40

SIDE Scale Heritability and Environmentality Estimates

Scale	h^2_N	d^2	c^2	e^2
Sibling Interaction				
Antagonism	.000	.000	.055	.945
Caretaking	.232	.000	.000	.661
Jealousy	.000	.000	.327	.672
Closeness	.000	.000	.153	.846
Parental Treatment				
Maternal Affection	.420	.000	.000	.627
Maternal Control	.000	.000	.168	.832
Paternal Affection	.000	.000	.166	.834
Paternal Control	.000	.000	.181	.773
Peer Characteristics				
College Orientation	.558	.000	.000	.599
Delinquency	.000	.000	.156	.845
Popularity	.000	.000	.241	.759

Table 4.41

Family Environment Scale Heritability and Environmentality Estimates

Scale	h^2_N	d^2	c^2	e^2
Relationship Dimension				
Cohesion	.581	.000	.000	.420
Expressiveness	.389	.000	.000	.612
Conflict	.605	.000	.000	.394
Personal Growth				
Independence	.998	.000	.000	.001
Achievement	.500	.000	.000	.500
Intellectual-Cultural	.576	.000	.000	.425
Active-Recreational	.530	.000	.000	.471
Moral-Religious	.000	.000	.521	.403
System Maintenance				
Organization	.000	.000	.438	.561
Control	.000	.000	.424	.576

Table 4.42

Classroom Environment Scale Heritability and Environmentality Estimates

Scale	h^2_N	d^2	c^2	e^2
Relationship Dimension				
Involvement	.000	.000	.287	.712
Affiliation	.000	.000	.285	.714
Teacher Support	.000	.000	.256	.745
Personal Growth				
Task Orientation	.320	.000	.000	.681
Competition	.000	.000	.270	.729
System Maintenance				
Order and Organization	.000	.000	.335	.664
Rule Clarity	.196	.000	.000	.805
Teacher Control	.285	.000	.000	.716
Innovation	.276	.000	.000	.724

Table 4.43

Environmental Response Inventory Heritability and Environmentality Estimates

Scale	h^2_N	d^2	c^2	e^2
Pastoralism	.521	.000	.000	.479
Urbanism	.433	.000	.000	.567
Environmental Adaption	.000	.000	.376	.624
Stimulus Seeking	.612	.000	.000	.388
Environmental Trust	.000	.000	.347	.652
Antiquarianism	.537	.000	.000	.462
Need Privacy	.000	.000	.379	.621
Mechanical Orientation	.480	.000	.000	.520
Communality	.345	.000	.000	.656

is very small and these aspects of personality appear to be primarily determined by environmental influences, the majority of which is of the nonshared variety. The Desirability scale is the only scale that shows substantial shared environmental variance (.523). This result suggests that the response set of social desirability is affected by environmental effects common to a pair of twins. This finding of a zero heritability for some aspects of personality suggests that the genetic influence is not as influential as the earlier research would tend to suggest.

The MMPI scales typically show higher heritabilities (median .501). They range from an effective low of zero to a high of .651 with the majority falling in the .50 to .60 range. This result would seem to suggest that liability to personality disorder is somewhat more heritable than is normal personality - that is, that the fundamental difference between normalcy and abnormality is genetic. However, this would be a gross overinterpretation, since the differences are not very large. Many of the MMPI heritability estimates are similar to those obtained by Vandenburg (1967). Using Falconer's method to obtain the heritability estimates from the correlations in his paper (see Chapter 1), very similar results between his and the present study were obtained for Social Introversion (.66 *vs*

.63, respectfully), Depression (.60 *vs* .57, respectfully), and psychasthenia (.60 *vs* .64, respectfully), as examples. A number of the estimates from the present study are more than twice the size obtained by Vandenburg, however. These scales are Hypochondriasis, Hypomania, and Masculinity-Femininity. The fact that some of the estimates are stable across studies and some are not suggests that some aspects of personality disorder are more genetically robust than others.

Three MMPI scales have small genetic components that are overwhelmed by environmental factors. These are the Lie (L), Ego Strength, and MacAndrew Addiction scales. No comparisons can be drawn between the Ego Strength and MacAndrew Addiction scales with earlier research because these scales did not exist then. The heritability of the Lie scale (indeed, any of the validity scales) has not been presented before this study. Some may question including them for analysis but given that these scales, especially on the MMPI, have come into their own as clinical measures of behaviour, their inclusion is justified. The results suggest that whether one lies on the MMPI, is tough-minded, or falls into substance abuse is primarilly learned. It is interesting to speculate whether the finding that the shared environmental component is slightly larger than the nonshared component (.521 *vs* .479, respectively) on the MacAndrew Addiction scale which supports the common belief that alcoholism is learned from parents, or the general attitude towards alcohol in the home.

The SIDE was designed as a measure of nonshared environmental influences and the majority of the variance on the absolutely scored SIDE scales is nonshared in nature. The median nonshared environmental variance estimate is .834. The estimates range from a low of .599 on Peer College Orientation to .945 for Antagonism. In general, these results are somewhat at variance with Baker and Daniels' (1990), who report finding a genetic influence on all the SIDE scales. Nevertheless, the present results are in line with the earlier finding of little genetic influence on the SIDE (Plomin and Daniels, 1985). Replication on an independent sample is clearly necessary. However, some scales in the present study do show genetic influences, with two scales showing substantial additive genetic effects. These are Peer College Orientation (.558) and Maternal Affection (.420). Perceptions of sibling Caretaking and Paternal Affection also have a small additive genetic component, estimated at .232 and .194, respectively.

All but three of the FES scales show substantial genetic influences. Typically, the heritabilities centre around .50, with the remainder of the variance being attributable to nonshared environmental effects. Almost all of the variance (99.8%) in Independence is attributable to additive genetic factors. This result suggests that a person's perception of the extent to which family members are assertive, are self-sufficient, and make their own decisions is almost completely genetically influenced. Three scales of general family environment appear to be little influenced by heredity. These are family Moral-Religious emphasis, and both the "System Maintenance" dimensions of Family Organization, and Control. This implies that the degree of emphasis on ethical and religious issues, the degree of importance of clear organization and structure in planning family activities and responsibilities, and the extent to which set rules and procedures are used to run family life are primarily learned.

The CES is much more of an exogenous measure of the environment than is the FES. The scales show little genetic influence that range from 32% to none at all. Furthermore, the majority of the variance is of the nonshared environmental variety. The median e^2 is .724, the lowest estimate obtained was .681 for Task Orientation and the highest .805 on Rule Clarity. Although a model specifying additive genetic and nonshared environmental effects (the AE model) fits best for a number of the CES scales, the majority of the variance is due to nonshared effects. The small genetic component may mean that some perceptions of school life are genetically influenced. For example, although the scale reflects school events as they may have happened, whether they are perceived as positive or negative experiences may be influenced by a genetically influenced trait such as one's level of Affiliation (the extent to which one enjoys being with friends, makes an effort to make friends, etc.). Overall however, the CES appears to be an exogenous measure of the environment.

All but two of the ERI scales show substantial additive genetic influences that centre around .50. This indicates that a person's attitudes toward the environment is substantially heritable. The two exceptions are Environmental Adaption and the Need for Privacy scales, which have a zero heritability. Nonshared environmental effects make up the bulk of the environmental variance on all scales. This measure is something of a puzzle. It is on the one hand purported to be a measure of the environment, but at the same time it is a measure of attitudes. The instrument thus lies at the interface between nature and nurture, and this may account for the finding that it yields heritability estimates which are similar to those obtained from self-report personality measures.

In sum, the heritability estimates computed on the PRF scales are largely commensurate with those found with other personality measures. Heritability estimates on the MMPI are similar. Many of the FES and ERI scales show substantial genetic influence whilst the CES shows very little. The SIDE shows genetic influence on some of its scales but the majority of its variance is directly attributable to nonshared environmental influences. In general, genetic effects on the environmental measures appear to affect specific scales, particularly those concerning primary care-givers and peers.

Multivariate Genetic Analyses

The correlation of each PRF scale and MMPI scale produced a number of significant coefficients. Most of these significant Pearson correlations were low, with the majority being no larger than .35. Apparent among the correlation matrix were a number of phenotypic correlations amenable to multivariate genetic analyses from a psychological and statistical perspective. Two groups of correlations were identified. The first shows that Social Introversion (Si) from the MMPI correlates with three different PRF scales. Affiliation (Af), Exhibition (Ex), and Change (Ch) correlate with Si at -.5418, -.6023, and -.2956, respectively, ($p < .001$). These relationships are straightforward to interpret as the greater the tendency toward introversion and extreme shyness, the less one enjoys being with friends and maintaining social contacts, or being the centre of attention, and the less likely one is to require change and a variety of new and different experiences. The intercorrelations of Af, Ex, Ch, and Si are presented in Table 4.44. The second set of correlations is between the Desirability scale (Dy) of the PRF and the three MMPI validity scales, Lie (L: $r = .2629$), Infrequency (F: $r = -.4172$), and Defensiveness (K: $r = .3980$). All the correlations are significant at $p \leq .05$. Some description of the MMPI validity scales is necessary to interpret these correlations. The L scale was designed to detect individuals attempting to present themselves in an overly favourable way. The K scale measures a person's tendency to

Table 4.44
Intercorrelation of Selected Personality Research Form and Minnesota Multiphasic Personality Inventory Scales: Si, Af, Ch, and Ex

	SI	AF	CH	EX
SI	1.0000	-.5418	-.2956	-.6023
	(0)	(249)	(249)	(250)
	P= .	P= .000	P= .000	P= .000
AF	-.5418	1.0000	.1419	.4764
	(249)	(0)	(275)	(275)
	P= .000	P= .	P= .019	P= .000
CH	-.2956	.1419	1.0000	.3523
	(249)	(275)	(0)	(275)
	P= .000	P= .019	P= .	P= .000
EX	-.6023	.4764	.3523	1.0000
	(250)	(275)	(275)	(0)
	P= .000	P= .000	P= .000	P= .

hide or to deny psychological problems, and the F scale was designed to detect individuals who attempt to fake bad or, who take an unusual approach to the test. Their relationship to the PRF Desirability scale indicates that individuals who try to present themselves in a favourable manner on the PRF will do the same on the MMPI, but will also try to hide any psychological problems and will try not to look poorly on the test. The intercorrelations of L, F, K, and Dy are presented in Table 4.45.

Bivariate biometric models as illustrated in Figure 4.1 were fitted to each pair of variables. Model fitting results are presented in Table 4.46. Each set will be discussed in turn. A satisfactory fit was obtained between Si and Af, and Si and Ch. A poor fit was obtained between Si and Ex. Heritability and environmentality coefficients were estimated for common and unique components of variance for the variables where a satisfactory fit was obtained. These are presented in Table 4.47. A strong genetic correlation is indicated between Si and Af. About 77% of Si's common genetic variance comes from the same source as Af's. Almost 40% of Af's shared genetic component is attributable to the same source as Si's. Si appears to not have any of its shared environmental variance in common with Af, but each variable has some nonshared environmental

Table 4.45
Intercorrelation of Selected Personality Research Form and Minnesota Multiphasic Personality Inventory Scales: Si, Af, Ch, and Ex

	DY	L	F	K
DY	1.0000	.2629	-.4172	.3980
	(0)	(250)	(249)	(250)
	P= .	P= .000	P= .000	P= .000
L	.2629	1.0000	-.2620	.3732
	(250)	(0)	(249)	(250)
	P= .000	P= .	P= .000	P= .000
F	-.4172	-.2620	1.0000	-.5303
	(249)	(249)	(0)	(249)
	P= .000	P= .000	P= .	P= .000
K	.3980	.3732	-.5303	1.0000
	(250)	(250)	(249)	(0)
	P= .000	P= .000	P= .000	P= .

Table 4.46

Results of Multivariate Genetic Model Fitting

Scales in Model					
PRF	MMPI		χ^2	*p*	df
Af	Si		12.45	.132	8
Ex	Si		18.75	.016*	8
Ch	Si		9.17	.282	8
Dy	L		3.03	.932	8
Dy	F		12.19	.143	8
Dy	K		26.51	.001*	8
Dy	L	F	27.20	.295	24

Note: * significant at $p \leq .05$.

Table 4.47

Common and Unique Heritability Estimates

Scales in Model	Common h^2_N	c^2	e^2	Unique h^2_N	c^2	e^2
Af & Si:						
Af	.384	.228	.388	.240	.000	.761
Si	.771	.000	.230	.102	.000	.898
Ch & Si:						
Ch	.532	.000	.468	.510	.000	.490
Si	.500	.000	.500	.628	.000	.371
Dy & L:						
Dy	.298	.542	.160	.000	.273	.727
L	.118	.693	.189	.000	.256	.744
Dy & F:						
Dy	.086	.821	.093	.066	.000	.934
F	.413	.367	.220	.151	.000	.849
Dy, L, & F:						
Dy	.042	.877	.270	.104	.000	.896
L	.241	.374	.385	.000	.461	.539
F	.493	.255	.251	.000	.000	1.000

influences in common. The relationship between Ch and Si is very clear. Approximately half of the shared genetic variance between Si and Ch is from the same source, with the other half coming from the same sources of the nonshared environment. Si and Ch have no shared environmental influences in common. The poor fit of the model that tests for common genetic and environmental influences between Ex and Si indicates that the observed phenotypic correlation between them does not have a common genetic or environmental etiology. Although they appear to be related at a behavioural level, the underlying bases of the behaviours operate independently. The bivariate genetic model was also fitted to Dy and L, Dy and F, and Dy and K. A common underlying etiology was found between Dy and L and Dy and F, but a poor fit was obtained between Dy and K. These are presented in the lower half of Table 4.46. Specifically, although a genetic correlation was found between Dy and each of L and F, the magnitude of the environmental correlation is much greater. Over 60% of the environmental variance in Dy and almost 90% of the variance in L stem from the same environmental sources, which are primarily of the shared kind in nature. When Dy is paired with F, approximately 90% of the common variance with F is environmental in nature, whereas about 60% of the variance in F is in common with DY. With this pairing, the partitioning of the common environmental variance is almost completely attributable to shared effects in Dy (82%), whereas 37% is attributable to shared effects in F, with the remaining 22% to nonshared effects.

The analysis of Dy with each of L and F found a noticeable environmental correlation. An additional analysis between these variables is also possible. It is appropriate to fit a trivariate genetic model to Dy, L, and F because the phenotypic intercorrelation between L and F is also significant (-.262, see Table 4.45). The trivariate model fitted is illustrated in Figure 4.2 and is a simple extension of the bivariate model presented in Figure 4.1. This model produced a satisfactory fit to the data (see Table 4.46). Computation of common heritability and environmentality coefficients shows a moderate genetic correlation between these three variables and a somewhat larger environmental correlation between them. Only 4% of the genetic variance in Dy is common to L and K, whereas 24% and 49% of the genetic variance in L and F is common.

Approximately 88% of the variance in Dy is of the shared environmental type which is common to L and F. About 37% of L and 26% of F is due to shared environmental variance in common among all three variables. The rest of

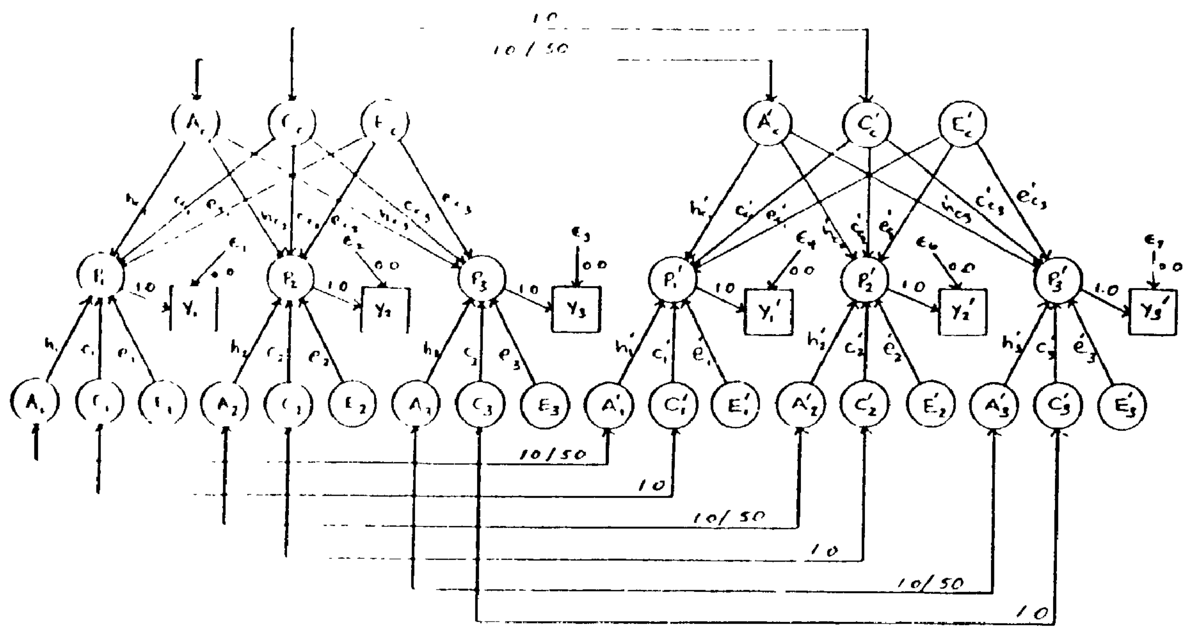


Figure 4.2. *Trivariate Biometric Model.* A_c, C_c, E_c denote the genetic variation, shared environmental variation, and nonshared environmental variation common to the phenotypes (P_1,...P_n). The primes (′) denote the corresponding variables for the second twin. Y_1,... and Y_n denote observations on the first and second twins. Parameters h_{c1}, c_{c1}, e_{c1},...h_{cn}, c_{cn}, e_{cn} are the maximum likelihood parameter estimates which are used to form h^2_{c1}, c^2_{c1}, e^2_{c1},...h^2_{cn}, c^2_{cn}, e^2_{cn} estimates. A_1, C_1, E_1,...A_1, C_1, E_1 denote the genetic variation, shared environmental variation, and nonshared environmental variation unique to the phenotypes (P_1,...P_n). Parameters h_1, c_1, e_1,...h_n, c_n, e_n are the maximum likelihood parameter estimates which are used to form h^2_1, c^2_1, e^2_1,...h^2_n, c^2_n, e^2_n estimates. Standard LISREL notation has not been included on the figure for most latent and observed variables and parameters for clarity.

each variable's common variance is of the nonshared environmental variety. Common nonshared environmental variance accounts for only 27% of Dy, 39% of L, and 25% of K. Clearly, what binds all three of these variables together is a common environmental basis, the majority of which is of the shared variety.

These results clearly show that there is a definite link, or continuity between measures of normal personality function as measured by the PRF and liability to personality disorder as measured by the MMPI. These genetic and environmental correlations indicate that some traits of normal personality and some personality disorders share the same etiology and argue for a dimensional conceptualization of normal and abnormal personality as opposed to a categorical one. This suggests that current categorical classifications of pathology may not adequately capture the nature of the phenomena and that personality disorder may sometimes represent the extremes of normal personality function. For example, as demonstrated in this research, pathological shyness and introversion is the opposite extreme of affiliation and need for change. Furthermore, this extreme shyness comes from genetic and environmental sources that exist and operate independently of those common genetic and environmental effects that underlie exhibitionism.

These analyses have shown that research on the relationship between normal and abnormal personality, and the genetic and environmental influences common to both, is possible. What is needed now is a thorough analysis based on a larger sample size and more importantly, employing better measures of personality disorder. This latter requirement is particularly salient because the MMPI may not be the best measure of liability to personality disorder. This is because the MMPI scales are all significantly intercorrelated with one another and there is little definition between the various disorders (median positive $r = .3794$, $p \leq .001$; median negative $r = -.3216$, $p \leq .001$; range $r = -.7710$ to $r = .9100$). As such, the MMPI may only be measuring one general factor of pathology - general deviant behaviour. This may explain the presence of a large number of small, statistically significant, but uninterpretable, PRF - MMPI correlations.

Stage 3: Differential Experience Related to Differential Personality

The model-fitting and heritability analyses presented above have clearly found that a large proportion of the variance in the personality and environmental measures is directly attributable to nonshared environmental factors. As such, it makes sense to proceed to try to identify any systematic relationships between differences in sibling experience and differences in personality and liability to personality disorder. The results of this set of analyses are presented in Tables 4.48 to 4.50, but can be neatly summarized in a single word - dismal. Only a single MZ personality difference was found to be predictable by the measures of differential sibling experience, in addition to which three DZ personality differences, and five non-twin personality differences were predictable. This gives a total of only nine relationships revealed for the entire study. Given that this study has 45 predictors (11 SIDE scales, 10 FES scales, 9 CES scales, 9 ERI scales, and 6 items from the twin questionnaire, including age and gender) and 39 dependent variables (22 PRF scales & 17 MMPI scales), there are 1755 possible predictions for each group, or 5265 for the entire study! Given this number of possibilities, a case could be made that those few significant results found are no more than Type I errors. This is particularly likely to be the case if the relationships do not have any substantive meaning. Loehlin and Nichols (1976) came much to the same conclusion. They found some tendency toward correlation between early experience and differences in

Table 4.48

Regression of MZ Twin Personality Differences on Differential Sibling Experience Scales

Sibling Personality Difference	Significant Environmental Predictors	R	R^2_{ADJ}	β
Schizophrenia[1]	Differential Peer Delinquency[3]	.48	.184	.48*

Note: *p ≤ .05; [1]Scale from the MMPI; [2]Scale from the PRF; [3]Scale from the SIDE; [4]Scale from the ERI; [5]Scale from the CES.

Table 4.49

Regression of DZ Twin Personality Differences on Differential Sibling Experience Scales

Sibling Personality Difference	Significant Environmental Predictors	R	R^2_{ADJ}	β
Impulsivity[2]	Environmental Trust[4]	.59	.30	.59*
Defensiveness[1]	Need Privacy[4]	.53	.24	.53*
Social Introversion[2]	Differential Peer Delinquency[3]	.50	.20	.50*

Note: *$p \leq .05$; [1]Scale from the MMPI; [2]Scale from the PRF; [3] Scale from the SIDE; [4]Scale from the ERI; [5]Scale from the CES.

Table 4.50

Regression of Non-Twin Sibling Personality Differences on Differential Sibling Experience Scales

Sibling Personality Difference	Significant Environmental Predictors	R	R^2_{ADJ}	β
Succorance[2]	Differential Maternal Affection[3]	.44	.16	.44*
Schizophrenia[1]	Teacher Control[5]	.45	.17	-.45*
Play[2]	Differential Paternal Control[3] & Achievement Orientation[6]	.57	.33	-.43*
Psychasthenia[1]	Differential Paternal Control[3] & Communality[4]	.58	.27	-.40*
MacAndrew Addiction Scale[1]	Differential Maternal Control[3]	.42	.14	-.42*

Note: *$p \leq .05$; [1] Scale from the MMPI; [2]Scale from the PRF; [3] Scale from the SIDE; [4]Scale from the ERI; [5]Scale from the CES; [6] Scale from the FES.

personality, but the correlations centred around .05 or .06 - not much different than that expected by chance alone. Loehlin and Nichols suggest simply that differential experience is random in nature and as such cannot be studied, at least by conventional methods. This is a point that will be returned to later.

Nevertheless, perhaps there may be something to be gleaned from the relations identified here. For the MZ twins, differences in liability to Schizophrenia on the MMPI were positively related to differences in Peer Delinquency from the SIDE. This result is interpretable as showing that the sibling whose peers engage in greater delinquent behaviour has a greater liability to schizophrenia. The Sc scale measures bizarre mentation, social alienation, and feelings of persecution. High scorers are described as indifferent, unlikeable, stubborn, hostile, lazy and undependable (King-Ellison Good & Brantner, 1974). Although this relationship is significant, Peer Delinquency accounts for only 18% of the variance in liability to Schizophrenia. The ratio of sibling variances (M & L) for Schizophrenia and Peer Delinquency is 1.38 and 1.06 respectively.

With the DZ twins, Environmental Trust from the ERI was positively related to Impulsivity from the PRF. The ratio of sibling variances for Impulsivity was 1.37, and for Environmental Trust it was 1.31. This relationship is interpretable as showing that the sibling who shows greater openness toward the environment (e.g., competence in finding one's way about the environment; not afraid of being alone and unprotected) is also the most impulsive. A high scorer on this PRF scale is described as tending to act on the "spur of the moment" and without deliberation; speaking freely; and is often described as being foolhardy, excitable, incautious, and impetuous (Jackson, 1986). This relationship appears to be reasonably strong with Environmental Trust accounting for approximately 30% of the variance in Impulsivity.

The second relation found among DZs was between Need for Privacy from the ERI and Defensiveness (K) from the MMPI. A high scorer on the K scale is described as self-managing, controlled, resourceful, ingenious, and versatile (King-Ellison Good & Brantner, 1974). This relationship is also positive and is interpreted as showing that the sibling who has the greatest need for isolation and who enjoys solitude the most is also more likely to engage in a defensive and guarded response style to items on the MMPI. Differences in Need for Privacy account for approximately 24% of the variance in differences in Defensiveness. The relationship between these two variables must be interpreted with caution because the ratio of sibling variance for Need for Privacy is somewhat high at 2.16. On the other hand, the ratio of sibling variance for Defensiveness is almost equal to unity at 1.10.

The final DZ relationship identified is between Sibling Peer Delinquency from the SIDE and Social Introversion from the MMPI. The ratio of sibling variance for Social Introversion is 1.11 and for Peer Delinquency it is 1.27. This relationship is interpretable as showing that the sibling whose peers engage in more delinquent behaviours is also the sibling who shows greater liability to social introversion. A social introvert is typically described as sensitive, avoidant of social contacts with others, suffering from inferiority discomfort, and having great physical somatic concerns (King-Ellison Good & Brantner, 1974). Peer Delinquency accounts for approximately 20% of the variance in Social Introversion.

It may seem odd that Peer Delinquency is predictive of different MMPI scales for MZs and DZs. Peer Delinquency is predictive of Schizophrenia in MZs and, as just reported, of Social Introversion in the DZs. If the effects of having delinquent peers were robust, they should be the same between groups. However, King-Ellison Good and Brantner (1974) note that the Social Introversion scale is related to Schizophrenia in that is indicates the degree of social withdrawal or shyness as a result of schizophrenic tendencies (p.40). The items on the Social Introversion scale measure a person's uneasiness in social situations; insecurities and worries; and denials of impulses, temptations and mental abberations (p.41). The Schizophrenia scale items reflect bizarre mentation, social alienation, peculiarities of perceptions, and concern with sexual matters, difficulties in concentration and impulse control, and fears and worries (p.36).

The first relationship found with non-twin siblings is between Succorance from the PRF and Maternal Affection from the SIDE. Maternal Affection accounts for about 10% of the variance in Succorance. The ratio of sibling variances for Succorance and Maternal Affection are 1.14 and 1.27, respectively. This relationship is interpretable as showing that the sibling that experienced the greatest maternal affection also displays the greatest need for succorance. A high scorer on this PRF scale is described as one who frequently seeks sympathy; protection; love; and the advice and reassurances of other people. Defining trait adjectives include trusting, ingratiating, dependent, defenceless, and craving affection (Jackson, 1986).

The second relationship identified for this group is between Teacher Control from the CES and the Schizophrenia scale from the MMPI. Teacher Control accounts for 17% of the variance in Schizophrenia and the relationship is negative. Both ratios of sibling variance are near unity at 1.23 for Schizophrenia and 1.13 for Teacher Control. The sibling who experienced the greatest teacher control (e.g., how strict the teacher is in enforcing the rules, severity of punishment) is also the one who is the least liable to schizophrenia. This negative relationship appears nonsensical, since it implies that having a lenient teacher may lead to schizophrenic tendencies. If anything, psychological theory would probably predict the opposite - that severe and strict teachers or paternal substitutes would be associated with social alienation, and feelings of persecution, and bizarre mentation. Because the relationship between these variables is so unlikely, it can best be discounted as no more than a manifestation of Type I error.

The third relationship identified among NT siblings makes much more sense. Play from the PRF is predictable by two environmental variables. Differential Paternal Control from the SIDE has a positive effect whereas Achievement Orientation from the FES has a negative effect. In combination they account for 26% of the variance. The ratio of sibling variances is 1.16 for Play, 1.18 for Paternal Control, and 1.40 for Task Orientation. This relationship is thus interpretable as showing that the sibling who experiences greater paternal control and perceives less emphasis on the extent to which activities (such as school and work) are cast into an achievement-oriented or a competitive framework, is also more jovial, frivolous, carefree, and blithe and is disposed to spend a good deal of time participating in games, sports, and social activities.

The fourth relationship identified is the negative association between Pyschasthenia from the MMPI and Paternal Control from the SIDE and Communality from the ERI. These two variables' joint effects account for approximately 27% of the variance in Psychasthenia. The ratio of sibling variance is 1.15 for Psychasthenia, 1.18 for Paternal Control and 1.13 for Communality. The Communality scale is the ERI validity scale that measures test-taking honesty. Their relationship is interpreted as showing that the sibling who experiences more paternal control and who answers questionnaires honestly is the sibling who is least likely to be troubled by obsessive ideas and fears. This sibling is also described as having fewer problems with study habits, fewer personal relationship difficulties, and having less trouble getting along with authority figures (King-Ellison Good & Brantner, 1974, p.35). King-Ellison Good and Brantner also report that college age students who score high on this scale are particularly conscientious in reporting for psychological experiments!

The final relationship found among the NTs is between the MacAndrew Addiction Scale from the MMPI and Maternal Control from the SIDE. This relationship is negative and accounts for only 13% of the variance. The ratio of sibling variances are close to unity for both variables: 1.17 for the MacAndrew Addiction Scale and 1.10 for Maternal Control. The relationship is interpretable as showing that the sibling who experienced the least maternal control also has the greatest liability towards substance abuse and addiction.

Beyond these specific relationships, some general trends are discernible from these results. First, more non-twin differences than DZ differences, and more DZ differences than MZ differences are predictable. This may be because the non-twin sibling differences are greater than are those between MZ or DZ twins. Second, more differences in personality disorder as measured by the MMPI are predictable than are those from the PRF, despite the fact that the magnitude of the nonshared environmental components on these instruments are roughly similar in size, and overall, for the MMPI scales are slightly smaller. A third observation is that more of the differential sibling experience variables that contribute to differential personality are concerned with peers and parental/teacher controls, as compared with other variables such as sibling interaction. Perhaps liability to personality disorder is related to these factors in particular; a finding similar to that found by Baker and Daniels (1990). A final observation is that for all predictors, the R^2_{ADJ}'s are uniformly quite low, accounting for only a moderate amount of the variance (18% to 30%). This indicates that the measures of differential sibling experience employed in this study have little power to predict sibling personality differences. Perhaps a greater range of measures is necessary, and it might also be fruitful to limit study to psychopathology with this approach.

Beyond the few relationships found, and the moderate amount of variance accounted for, the biggest difficulty with these results is that they are <u>not</u> consistent and do not generalize over the three kinship groups. Furthermore, there appears to be no systematic zygosity effect - the relationships identified almost appear to be random. MZ differences are less than DZ differences and DZ differences are typically less than NT sibling differences. As such, one might expect that a relationship found among MZs would also be found among DZs and even more so among the NT siblings. This is not the case with the present data. This result may speak to the nature of nonshared environmental effects - perhaps these effects are truly random.

Simply declaring nonshared environmental effects to be random, however, and concluding that they are not amenable to study would be defeatist. A more promising approach may lie in attempting to understand how nonshared environmental factors are related to differential personality development. Such an investigation would require the study of independent and dependent variables over time. Repeated measures analyses may reveal that relationships between these are nonlinear, developmental, or discontinuous. Such a study would have the potential to identify which independent variables are related to which dependent variables, and could elucidate the nature of their relationships. The present research had subjects average out their experiences over time and thus may have masked relationships that might appear at specific points of time in a repeated measures design.

There are a number of other possible reasons why so few significant results were obtained here. One limitation of this study is its rather small sample size and attendant lack of statistical power. For example, the DZ sample has only about 29% power to detect a correlation as low as .20 as significant ($p \leq .05$, two-tailed). The only remedy is to increase the sample size until adequate power is obtained to exploit the small differences that exist. A sample of 197 pairs would be required for 80% power to detect a correlation of .20 as significant ($p \leq .05$, two-tailed). Pooling the three kinships would have yielded the required number of pairs. This was not done because too many significant differences in differential sibling personality and experience exist between the kinship groups (twins *vs* nontwins). Moreover, success is not guaranteed even with a larger sample size. Plomin and Daniels (1985), for example had almost 400 pairs of siblings and their predictors also accounted for no more than 30% of the variance.

Improvements could also be made in the measurement of nonshared environmental experiences. Eaves, Neale, and Meyer (1991) noted that the comparative strategy of the SIDE is appealing, but that the relative scores cannot be analyzed in the same way as more familiar absolute scores. Eaves *et al.* (1991) outline a method that uses comparative ratings between pairs of siblings (or other relatives) that are convertible to estimates of within-pair true score variances. The approach is based on Signal Detection Theory and accounts for how a typical first sibling in a pair arrives at a comparative rating of self in relation to his or her co-sibling. Research with this method will require the collection of new data, where siblings are required not only to rate each other, but also themselves on a particular attribute.

General Discussion

The research described here was an attempt at a behavioural genetic analysis of a broad spectrum of personality. The goal of the research was not only to corroborate previously published research findings, but to expand these findings in a substantial manner. This expansion involved analyses and measures not yet routinely used in the study of personality. Basic heritability and environmentality estimates for a number of popular scales were presented for the first time. These scales included measures of normal personality and liability to personality disorder, as well as a number of well-known measures of the so-called "environment". The estimation of possible genetic influences on measures of the environment is crucial as it represents the first step in understanding if our preexisting perceptual biases influence perceptions of the exogenous environment and how they are reacted to, or if the environment has a direct role in influencing personality. Furthermore, basic behavioural genetic research on personality disorder is rather sparse.

The genetic analyses conducted here also went beyond previous work by testing for and estimating the magnitude of nonadditive genetic effects that may have been present. The effects of genetic nonadditivity have often been discussed in personality research but there have been very few empirical studies that have estimated their actual magnitude. Moving beyond the univariate genetic analyses, a number of multivariate genetic analyses were also conducted specifically to determine if a genetic correlation, or, common genetic and environmental etiology is behind normal personality and liability to personality disorder. These analyses are the first to <u>directly</u> examine the nature of normal and abnormal personality in this manner: that is, to reveal whether a common or a completely independent biological or environmental etiology underlies the pnenotypic or behavioural relationships often observed.

As a final step in any reasonably comprehensive analysis of personality, this study attempted to identify sources of nonshared environmental influences related to personality and personality disorder. This investigation expanded upon the difference score approach first used by Loehlin and Nichols (1976) and later by Plomin and Daniels (1985). This involved the use of more measures and a modified methodology primarily centring on absolute value difference scores as opposed to signed difference scores, and the use of twins and nontwin siblings in a single analysis. Absolute value difference scores were hypothesized to attenuate or eliminate a number of statistical and conceptual difficulties thought to mask relationships between nonshared environment and personality differences. .he use of twins and nontwin siblings was also thought to provide a greater range of experiential differences, and thus augment the detection of any relationships between nonshared environment and differential personality.

The heritability estimates on the PRF were presented for the first time and they were found to be very similar to those obtained with other personality measures. This scale and liability to personality disorder (as measured by the MMPI) have substantial genetic and nonshared environmental components. However, it is interesting to note that there is some indication that the genetic influence is not particulalry large on some scales. Although a genetic component is present in all PRF and MMPI scales, as evidenced by the fit of the full ACE model, purely environmental factors could, on their own, account for all of the variance in some traits. This is the case with such traits as ego strength, liability to substance abuse and addiction, abasement, and dominance. With these traits, environmental influences are central.

This finding of differential heritability may be somewhat at variance with previous published results that typically find rather homogeneous heritability estimates in the .40 range. The reason for this may be that the PRF presents a very detailed portrait of personality. The scales on this measure are not highly intercorrelated, averaging around .20, and thus each scale is measuring a different trait. The research reviewed earlier typically employed scales measuring the so-called personality super-factors of Neuroticism and Extraversion, or their derivatives. These other scales have much higher scale intercorrelations and may be measuring no more than these two super-factors, and this would account for the homogeneity. With the PRF at least, differential heritability is indeed possible and expected.

Finally, this investigation also showed that nonadditive genetic effects attributable to genetic dominance were found to be present on a large number of traits, but their magnitude was small to negligible. Similarly , environmental variance due to shared effects was also found to account for only a minute portion of the variance in most of the traits tested. This result is very similar to results reported by other research.

The multivariate genetic analyses showed that some aspects of normal personality and personality disorder can share a common genetic and environmental etiology. The two examples here show that the underlying continuity is typically genetic and environmental in nature. The implication of demonstrating a genetic and environmental correlation between normal personality and personality disorder argues for a dimensional conceptualization of personality disorder rather than a categorical one. Currently, the only other attempts to investigate the genetic continuity have involved showing that the heritability of "normal" scores on a particular test is similar to that obtained from extreme scorers (Defries & Fulker, 1985, 1988). This interpretation of finding similar heritability estimates for normal-range and extreme scores is still questionable, even if found. It could be that different gene complexes underlie each trait to about the same degree. As such, this limitation clearly demonstrates that multiple measures of normal and abnormal functions should be made standard practice when collecting personality data on twins. This allows for the fitting of multivariate genetic models that can directly test for genetic and environmental correlations between measures and obviates the need for less direct methods.

The heritability analyses of the environmental measures reported here are similar to Plomin and Bergeman's (1991) finding that many of the so-called environmental measures show a genetic influence. However, some of the present results are at variance with theirs. This discrepancy may be attributable to exactly what scales, or more accurately, what form of the scales were subjected to genetic analyses. Plomin and Bergeman's review implies that genetic influences appear on all scales of certain environmental measures. This is misleading because the results they report are based on the aggregation over a number of scales as opposed to examining each of the scales separately. For example, Plomin and Bergeman report FES results based on two scales derived from a factor analysis of all 10 FES scales. The present study deliberately used all 10 scales as designed, in order to get maximum discrimination and detail between scales and their parent measures. This strategy appears to be successful, because the results here show something different than Plomin and Bergeman's review would suggest. It is not that no genetic effects were found on the environmental measures, but rather that they are specific to some scales and not to others. This finding allows for greater specificity in measurement selection and use.

The CES was the only measure in which all constituent scales proved to be exogenous measures of the environment. This scale was shown to be relatively uncontaminated by genetic influences. However, this is the first report on the CES and it needs to be replicated on an independent sample. A number of the SIDE scales were shown to be relatively uncontaminated by genetic effects. This result is at variance with some reports that find the SIDE has a substantial genetic component (Baker and Daniels, 1991) but is in line with others that find little (Plomin and Daniels, 1985). The SIDE was designed at the outset to be a measure of differential experience and the scale's authors appear to have succeeded in their task, for this scale has the largest proportion of its variance directly attributable to nonshared environmental factors of all the scales used in this study. The ERI, which deliberately fuses personality and attitudes with the environment, shows heritability coefficients similar to those found with other personality scales as opposed to environmental measures.

Although a large nonshared component was found for all the variables used in this study, the identification of what this might be uncovered very little. The most interesting information to be gleaned from these results is that more personality differences as measured by the MMPI are predictable than are those from the PRF. This differential predictability cannot be explained by differences in the magnitude of nonshared effects because the magnitude of nonshared influences are roughly similar for both the MMPI and PRF scales. This suggests that there is a fundamental difference in the way behaviour at the extremes of a normal distribution are affected by nonshared environmental events.

The reason so little of the variance in differential personality could be accounted for by nonshared environmental effects may be that these effects are generally nonlinear, developmental, or both in nature. This research, and the research of others, was based on the assumption that nonshared environmental effects were linear in their effects on personality. This notwithstanding, there still seem to be some aspects of nonshared environmental effects that are linearly related to personality differences: for example, effects concerned with treatment by authority or lack of authority figures such as peers and parent/teacher controls. This finding is similar to that found by Baker and Daniels (1990).

To try to interpret these findings any further would be extremely tenuous at best. The results are not consistent across the three kinship groups, they account for a small proportion of the variance in personality and personality disorder, and one of the relationships was found not to make any psychological sense. When these results are taken with the previously published research, it becomes clear that alternative approaches to those used here may be required.

Clearly, the search for nonshared environmental effects has consistently turned up very little despite much careful effort, and it may be time to entertain the idea that perhaps no systematic nonshared environmental effects exist. Current wisdom (or dogma) is that because MZ twins share all of their genes, any differences between them can only be due to nonshared environmental factors and measurement error. However, there is an increasing body of literature that challenges the most basic ideas of the twin method. For example, Cote and Gyftodimou (1991) suggest that MZ twin discordance is due to the "crossing-over" of homologous chromosomes immediately prior to the twinning process when the fertilized ovum begins its first cell division. Crossing-over during mitosis (cell division where there is no halving of the nuclear cell material) is the phenomenon that occurs when homologous chromosomes literally cross over one another, with parts of one chromosome physically lying on top of parts of the other. The parts that are touching then break off, with the broken portions rejoining the opposite chromosome. In this way one can be monozygotic but suffer from differential inheritance. Cote and Gyftodimou give the example that some animal species such as the armadillo regularly produce nonidentical but monozygotic quadruplets (p. 126). The effects of the mitotic crossing-over depends on a number of factors, such as the genes involved, the points of exchange, and so on. The consequences of having the recombinant genes can range from being lethal, to the development of gross structural anomalies, to the discordance of twins for congenital diseases and traits. Concurrent crossing-over of several chromosomes can cause further discordance, to the point of mimicking DZ twinning.

Mitotic crossing-over is just one of a number of possible genetic effects that could bring about differential inheritance in monozygotic twins. Other possibilities include mutation or differential lyonisation, for example, that may conspire to produce large differences between MZ co-twins quite independently of any exogenous nonshared environmental effects. It is interesting to speculate that if it was possible to measure all these effects, there might be nothing left for the exogenous nonshared environment to explain! The challenge is to design studies to shed light on these possibilities. Prominent researchers in behaviour genetics and medicine (e.g., N.G. Martin, personal communication; Nance, 1981; Elston & Boklage, 1977; Hall, Reed, McGillivary, Herrmann, Partington, Schinze, Shapiro, & Weaver, 1983) have been arguing for the study of these effects. The implications for behaviour genetic research and theory are tremendous. Heritability coefficients would be gross underestimates. Nonshared effects would be no better than negligible. Current theories and models would have to undergo considerable revision and this would bring about a fundamental change to the entire field. Cote and Gyftodimou write that,

"...the model's merits do not lie in its veracity or accuracy. Indeed, its primary value is to point out... (a) the inadequacies of the classical views on twinning and (b) the probable existence of a unified theory of genetics that will encompass the whole field and provide long-awaited answers to the problems posed by penetrance, expressivity, discordance, twinning, sex differences.... (p. 126).

Their conclusion brings us back to where this research began. It was remarked earlier that many have been calling for studies on the interface between heredity and the environment. However, these cannot be done until basic questions concerning heredity and the environment have been answered. Although immense progress has been made in the field, with new techniques and ideas, current behavioural genetic models remain relatively uncomplicated. They often look at no more than additive genetic effects, for example. Furthermore, so little of the full spectrum of human behaviour has been given even this cursory attention. The same can be said about the environment: here research has just begun. As such, it should perhaps not be surprising that the attempts to find nonshared environmental effects have uncovered very little at this time. It appears that the fundamental work of behaviour genetics will continue to be methodological and descriptive for some time to come.

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APPENDIX I: Twin Questionniare

Name: ____________________ (Code Number: __________)

As you know, there are two kinds of twins: identical (or monozygotic) twins, who have the same heredity, and fraternal (or dizygotic) twins, who share only part of the same heredity. The following questions are intended to help determine which kind you are. At the end, there are also some questions that ask you to think about any differences that may exist between yourself and your twin.

1. What is the natural color of your hair? ____________________

   If your hair is different from that of your twin in any of the following ways, please describe these differences:

   Natural Color: ____________________

   Rate of Crowth: ____________________

   Hairline or pattern of growth: ____________________

   Thickness or texture: ____________________

   Curliness: ____________________

   Other (Please specify): ____________________

2. What is the color of your eyes? ____________________

   If your eye color is different from that of your twin, please describe the difference: ____________

3. How tall are you? ____________________

How much taller (or shorter) are you than your twin? ____________________

4. How much do you weigh? ____________________

How much heavier (or lighter) are you than your twin? ____________________

5. If you know your blood type and Rh factor, please indicate them here: ________

6. As a young child, did your parents ever mistake you for your twin? (Check one)

__________ Yes, frequently

__________ Occasionally

__________ Rarely or never

7. Have your parents mistaken you for your twin <u>recently</u>? (Check one)

__________ Yes, frequently

__________ Occasionally

__________ Rarely or never

8. Have your teachers ever mistaken you for your twin? (Check one)

____________ Yes, frequently

____________ Occasionally

____________ Rarely or never

9. Have close friends ever mistaken you for your twin? (Check one)

____________ Yes, frequently

____________ Occasionally

____________ Rarely or never

10. Have casual friends ever mistaken you for your twin? (Check one)

____________ Yes, frequently

____________ Occasionally

____________ Rarely or never

11. Do you and your twin look alike? Please explain.

____

____

____

____

____

12. Describe those physical features which most clearly resemble those of your twin. (Give details)

13. Describe those physical features most <u>unlike</u> those of your twin. (Give details)

14. Do you know whether you are a fraternal or an identical twin? (Check one)

_____________ I know for sure that I am an identical twin

_____________ I think that I am an identical twin

_____________ I know for sure that I am a fraternal twin

_____________ I think that I am a fraternal twin

_____________ I don't know whether I am an identical or a fraternal twin

15. If you know whether you are fraternal or identical, how do you know? How and by whom was it determined?

16. Have you had any major illnesses or accidents that your twin did not have? If yes, please indicate the nature of the illness or accident and your age when it occurred.

____

____

____

____

____

____

17. Were you ever separated from your twin for more than a month at a time before the age of 18? If yes, please indicate where and with whom each of you lived, what you were doing, the reason for the separation, and your age at the time.

18. Have you had any important experiences or training which you or your twin has not had? Please explain.

19. What is (was) your grade average in high school?

(Circle one)

1. A+ (90-100)
2. A (85-89)
3. A- (80-84)
4. B+ (75-79)
5. B- (70-74)
6. C+ (65-69)
7. C- (60-64)
8. D or lower (59 or below)

20. For each of the following occupations, please write a number to indicate the amount of interest you would have. Consider only how well you think you would like the work connected with each occupation. Do not consider such factors as salary, prestige, required training, etc. (Your answer does not necessarily mean that you plan to enter the occupation). Make your answers as follows:

1. Like very much
2. Like somewhat
3. Neither like nor dislike
4. Dislike a little
5. Dislike a lot

1. Engineer ____
2. Physician ____
3. Accountant ____
4. Artist ____
5. Electrician ____
6. Lawyer ____
7. Shop Foreman ____
8. Farmer ____
9. Bookkeeper ____
10. Research Scientist ____
11. Business Manager ____
12. Sales Representative ____
13. High School Teacher ____
14. Writer or Journalist ____
15. Social Worker ____
16. Life Insurance Salesman ____
17. Building Contractor ____
18. Nurse ____
19. Architect ____
20. A Member of the Armed Forces ____

On this page, circle true (T) or (F) after each of the statements as they apply to you and your twin.

1.	We spend most of our time together	T	F
2.	We like each other a lot	T	F
3.	We attend the same school	T	F
4.	We have the same friends	T	F
5.	We tend to dress alike	T	F
6.	We like the same kinds of music	T	F
7.	We disagree about a lot of things	T	F
8.	We are in most of the same classes at school	T	F
9.	We have similar interests	T	F
10.	We like the same foods	T	F
11.	We have always spent a lot of time together	T	F
12.	Our parents treat us pretty much the same	T	F
13.	We like to read the same sorts of books	T	F
14.	We are each other's best friend	T	F
15.	We have never been apart for more than one month	T	F
16.	Our personalities are very much alike	T	F
17.	We like the same styles of clothes	T	F
18.	We have almost always had the same teachers	T	F
19.	We try to be different from one another	T	F
20.	We like the same movies	T	F

On this page, we would like you to answer the following questions:

How alike are you and your twin? Do you have the same attitudes, interests, and personalities, or are you different?

If you think that you are different from one another, what do you attribute this to? That is, what sorts of experiences have you had which your sibling has not had that you think may have contributed to your being different from one another?

Please answer in as much detail as possible. Continue on the back or ask for additional paper if you wish.

Are you primarily right or left-handed? ______________________

____

Are you (and your twin) the firstborn, or secondborn, or thirdborn, etc. children born in your family? ________________

____

____

If you know, who was born first: you or your twin? __________

____

If you know, approximately how much time elapsed between your and your twin's delivery at birth? ______________________

____

____

APPENDIX II: Items from the Sibling Inventory of Differential Exper'-.ce (SIDE: Daniels & Plomin, 1984)

Sibling completing questionnaire ______________________________

PLEASE READ THIS INTRODUCTION CAREFULLY

This questionnaire is designed to ask you and your sibling about what makes you different from each other as you are growing up. we would like you to compare yourself to your sibling (or one of your siblings, which we have specified below). For each question, think about what causes differences between you and your brother or sister. We will first ask you about differences in how you have interacted with your brother or sister. Then we will ask you how your parents have interacted with you and your sibling. Last, we will question you about your friends and other influences outside your home.

For the entire questionnaire, compare yourself to:______________________________.

For the entire questionnaire, think about your experiences in the past ______________________________.

I. Interactions With Your Sibling

Circle the appropriate number for each question. No item will apply in every situation, but try to consider what usually has happened between you and your sibling. Please answer quickly and honestly--there are no right or wrong answers. It should take about 20 minutes to complete this questionnaire.

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.

5 = I have been much more this way than my sibling.

For example: The first question asks who has started fights more often between the two of you. If your sibling nearly always has started the fights, you would answer by circling "1". If you nearly always have started them, you would circle "5". Circle "3" if there is no difference between you and your sibling (if you both start fights a lot or very little). If you don't know or can't remember, or if the question just doesn't apply to you, leave the question blank. (Avoid circling "3" or leaving the question blank whenever possible.)

1) In general, who has started fights more often?

2) In general, who has shown more trust for the other?

3) In general, who has shown more concern and interest for the other?

4) In general, who has been more willing to help the other succeed?

5) In general, who has liked spending time with the other more?

6) In general, who has been more likely to take responsibility for the other?

7) In general, who has been more stubborn with the other?

8) In general, who has shown more confidence in the other?

9) In general, who has acted more bitter toward the other?

10) In general, who has compared him/herself with the other more?

11) In general, who has been more likely to show feelings of anger toward the other?

12) In general, who has been more likely to feel superior over the other?

13) In general, who has shown more understanding for the other?

14) In general, who has been more likely to get jealous of the other?

15) In general, who has acted more kindly toward the other?

16) In general, who has been more likely to let the other

down?

17) In general, who has shown more affection toward the other?

18) In general, who has been more likely to deceive the other?

19) In general, who has been more bossy toward the other?

20) In general, who has been more likely to want to get along well with the other?

21) In general, who has been more supportive of the other?

22) In general, who has tried to outdo the other more?

23) In general, who has admired the other more?

24) In general, who has felt like the inferior one most?

II. Parental Interactions With You and Your Sibling

Circle the numbers separately for your mother and father. If your parents were divorced or if one died, answer the questions for the mother and father with whom you lived for the longest period of time. Remember to think about your experiences in the last ______________________.

For example: The first question asks if your parent has been stricter with you or your sibling. If your parent has been more strict with your sibling than with you, you should circle "1". if your parent has been much more strict with you, circle "5". Circle "3" if your parent has been equally strict with both of you. If you don't know or can't remember, of if the question just doesn't apply to you, leave the question blank.

25) Has been strict with us.

26) Has been proud of the things we have done.

27) Has enjoyed doing things with us.

28) Has been sensitive to what we think and feel.

29) Has punished us for our misbehavior.

30) Has shown interest in the things we like to do.

31) Has blamed us for what another family member did.

32) Has tended to favor one of us.

33) Has disciplined us.

III. Interactions With Your Peer Group

Circle the appropriate number for each characteristic below. Think of each item as if your peer group (your main group of friends) has a personality of its own. Even though friends inside each peer group might be quite different, think about how the group is in general. If you are unable to answer any question, please leave it blank--that is, do not circle any of the numbers for that question. Think about your experience in the last ________________________________.

For example: The first question asks whose group of friends has generally been the more popular. If your sibling usually "hung out" with a much more popular group of friends than yours, you would circle a "1". If you usually had a more popular group of friends than your sibling's peer group, you would circle a "5". Circle "3" if there is no difference between you and your sibling for the characteristic. Leave it blank if you don't know or if the characteristic does not apply to your peer group.

34) popular

35) ambitious

36) outgoing

37) lazy

38) hard working

39) intelligent

40) mature

41) extraverted

42) delinquent

43) responsible

44) successful

45) friendly

46) rebellious

47) conforming

48) well adjusted

Circle the appropriate number for each interest below.

Friends inside peer groups may have had separate interests, but rate the activity that best describes what the group has liked to do in general.

49) going on to college
50) achieving in school
51) student government
52) "partying," drinking, etc.
53) illicit drugs (such as marijuana)
54) political and social issues
55) achieving "status" in social situations
56) having a boyfriend or girlfriend
57) likely to skip class
58) likely to get along well
59) likely to be called the "bad" crowd

IV. <u>Events Specific to You or Your Sibling</u>

Circle the appropriate number for each of the questions below.

Think about your experience in the last ________________

60) Who has been more likely to go out on dates?
61) Who has been more likely to get in fights with their boyfriend or girlfriend?

62) Who has had a more difficult time breaking up with their boyfriend or girlfriend?

63) Who has been the one more likely to have an intense, close friendship?

64) Who has been the one to have more friendships at any one time?

65) Who has been more influenced by teachers in school?

66) Who has been more influenced by close relatives such as grandparents or aunts or uncles? Explain.

67) Who has been more influenced by meeting a special person? Explain.

68) Who has been more influenced by an extraordinary event? Explain.

69) Who has been more influenced by an accident or illness? Explain.

70) Who has been more influenced by the death of a loved one? Explain.

71) Who has been more influenced by parental separation or divorce? Explain.

72) Who has been more influenced by a family psychological problem? Explain.

73) Who has been more likely to have a psychological problem? Explain.

Appendix III: Items from the Environmental Response Inventory (McKenchie, 1971).

DIRECTIONS

This questionnaire is designed to study attitudes toward the environment. It contains a series of statements on various subjects. Read each statement and decide whether you agree or disagree with it. Use the following five categories to describe your response:

5 = strongly agree

4 = agree

3 = neutral

2 = disagree

1 = strongly disagree

Follow the instructions on the special answer sheet provided, and mark all of your answers on it. Please do not write in this booklet. Make sure that the number on the answer sheet is the same as the number of the question you are answering in the booklet. Try to answer each question, even if you must guess.

1. I like amusement parks.
2. I would enjoy the work of an architect.
3. Machines increase man's freedom.

4. I prefer to live in an area where neighbors keep to themselves.
5. I would enjoy driving a racing car.
6. The idea of walking into the forest and "living off the land" for a week appeals to me.
7. Life in the city is more interesting than life on a farm.
8. I would enjoy building a radio.
9. Traveling isn't really worth the effort.
10. I have my best thoughts when I am alone.
11. I enjoy browsing in bookstores.
12. I would be fun to move around and live in different parts of the country.
13. It is boring to spend all day working with your hands.
14. It is exciting to go shopping in a large city.
15. There should be a law against skyscrapers.
16. I like to be by myself much of the time.
17. I enjoy browsing in antique shops.
18. I sometimes daydream of being stranded on a tropical island.
19. I like places that have the feeling of being old.
20. I shudder at the thought of finding a spider in my bed.
21. I would enjoy traveling around the world on a sailing ship.
22. Alleys are interesting places to explore.
23. I prefer a stick-shift car to one with an automatic

transmission.

24. I like crystal chandeliers.
25. I like homes with stone floors.
26. I like the variety of stimulation one finds in the city.
27. I usually save spare nuts and bolts.
28. I get annoyed when my neighbors are noisy.
29. When buying clothes, I usually look more for comfort than for style.
30. I am quite skillful with my hands.
31. It's annoying to have to share an office or work space with someone.
32. I like to visit historic places.
33. Suburbs should replace the city as the center of cultural life.
34. I would enjoy working with precision power tools.
35. I have difficulty concentrating when things are noisy.
36. I would rather remodel an old house than build a new one.
37. We must move ahead and not worry about past failures.
38. Cities are too noisy and crowded for me.
39. I often feel uneasy in a large crowd of people.
40. I can repair just about anything around the house.
41. I often have trouble getting the privacy I want.
42. There should be a law against anyone owning more than a thousand acres of land.

43. I feel most secure when I am working around the house.

44. It is hopeless to try to save our cities.

45. It would be fun to own some old-fashioned costumes.

46. Motorcycles should be kept out of recreation areas.

47. I like modern furniture better than the more traditional styles.

48. I would like a job that involved a lot of traveling.

49. It is important for me to own top quality equipment.

50. As a child, I often watched when someone repaired things around the house.

51. I like the sounds of a city street.

52. Old sections of the city are more interesting than the new areas.

53. I often feel lonely when I am by myself.

54. As a child, I was taught respect for all living things.

55. It is good for man to submit to the forces of nature.

56. I prefer friends who are reliable and even-tempered.

57. I often think of settling down on a farm some day.

58. I don't like being completely alone.

59. I would like to live in a modern, planned community.

60. Zoning laws and other building controls are necessary to protect the rights of the public.

61. I like things that have precision moving parts.

62. I would enjoy entertaining famous people.

63. I often feel that I am a part of the space around me.

64. I can identify many of the local flowers and trees.

65. I would like to work with computers.

66. I have vivid memories of where I lived as a child.

67. Our national forests should be preserved in their natural state, with roads and buildings prohibited.

68. Flying in a small airplane would make me nervous.

69. As a child, I was afraid of being outside by myself.

70. It is better if people live out their lives in one place.

71. I would enjoy owning a fancy watch.

72. I would enjoy riding a motorcycle.

73. Making rain by artificially "seeding" clouds is a great technological advance.

74. I enjoy staying up all night.

75. I am happiest when I am alone.

76. No child should have to grow up in a rural area.

77. I get annoyed when people drop by my house without warning.

78. A fireplace adds a special feeling of coziness to a room.

79. It's interesting to learn about the history of the place where you live.

80. It is fun to make scale models of things.

81. I would enjoy living the rest of my life in a large city.

82. Electricity fascinates me.

83. I like social gatherings where I can enjoy meself

without worrying about other people.

84. I don't think that I would ever want to be hypnotized.

85. Small-town life is too boring for me.

86. Fertilizers improve the quality of food.

87. I often get the feeling that I just must be alone.

88. A person has a right to modify the environment to suit his needs.

89. Sometimes I'm afraid of too much stimulation--from sounds, colors, odors, etc.

90. I understand the architectural idea that form follows function.

91. I would enjoy working in a flower garden.

92. I enjoy owning a good piece of equipment, even if I don't get to use it much.

93. I pride myself on having a home which is always open to friends.

94. Fences make good neighbors.

95. I'd rather live in the suburbs than in the city.

96. A complex technological society cannot tolerate individuality.

97. I enjoy a change in the weather, even when it turns bad.

98. It is unsafe to ride on busses these days.

99. Country people are more honest than city people.

100. Hiking is boring.

101. I'd be afraid to live in a place where there were no

people nearby.

102. I find street noise very distracting.

103. I have always been somewhat of a daredevil.

104. I would enjoy riding in a crowded subway.

105. I am quite sensitive to the "character" of a building.

106. I like to ride on roller coasters.

107. I enjoy tinkering with mechanical things.

108. I do not like to loan things to neighbors.

109. I would enjoy living in a historic house.

110. Sometimes I wish I had power over the forces of nature.

111. I have no interest in ballet.

112. I like to read about the history of places.

113. Birth control practices should be accepted by everyone.

114. Jet air travel is one of the great advances of our society.

115. I have vivid memories of the neighborhood where I grew up.

116. I would enjoy going to the opera.

117. Today people are too isolated from the forces of nature.

118. It is easy for me to work undistracted in most situations.

119. I like to dress in the latest fashions.

120. I seldom pay attention to what I eat.

121. It is dangerous to work around heavy machinery.

122. The wilderness is cruel and harsh.

123. Modern buildings are seldom as attractive as older ones.
124. I like experimental art.
125. I often wish for the seclusion of a weekend retreat.
126. I would like to own an expensive camera.
127. Building projects which disrupt the ecology should be abandoned and the land returned to its natural state.
128. The problems of the cities will never be solved.
129. I am easily distracted by people moving about.
130. I often have trouble finding my way around a new area.
131. In spite of all the talk about pollution, the earth is still a safe place to live.
132. I need more variety in my life than other people seem to need.
133. I usually avoid public rest rooms.
134. I often have trouble figuring out how to use household appliances.
135. I usually enjoy having lots of people around.
136. I would enjoy watching movies made 15 or 20 years ago.
137. Natural resources must be preserved even if people must do without.
138. I like to get up early to see the sun rise.
139. I am afraid of driving in the city.
140. Trespassing laws should be more carefully enforced.
141. I am an adventurous person.
142. I often have strong emotional reactions to buildings.

143. There is too little emphasis on privacy in our society.

144. It is dangerous nowadays to live in a large city.

145. I seldom vary the route I take to everyday destinations.

146. It is important for me to feel that I am in harmony with the forces of nature.

147. When it comes to fixing things, I am hopeless.

148. Modern communities are plastic and ugly.

149. Science does as much harm as good.

150. I get upset if I must do too many things at once.

151. I would feel safer on the highway if speed limits were reduced.

152. I would like to take flying lessons.

153. Most jewelry is a waste of money.

154. I like to say hello to my neighbors.

155. I enjoy collecting things that most people would consider junk.

156. There are often times when I need complete silence.

157. I worry a lot about the rising crime rate.

158. The cultural life of a big city is very important to me.

159. I like to go shopping centers where everything is in one place.

160. I am fond of oriental rugs.

161. I am afraid of heights.

162. People who try to repair appliances themselves usually

end up breaking them.

163. I would like to live in a palace or a castle.

164. Sight-seeing is tedious and boring.

165. The cities contain the best aspects of modern life.

166. It's nice to buy a new car every year or so.

167. Bathtubs have become obsolete.

168. Places often play an important role in my dreams.

169. I would like to build a cabin in the woods.

170. I enjoy being in dangerous places.

171. Everyone should have the opportunity to live in a great city.

172. It's fun to walk in the rain even if you get wet.

173. Old buildings are usually depressing.

174. I would enjoy living on a houseboat.

175. Computers may someday take over the world.

176. I like to be on the move, not tied down to any one place.

177. Mental problems are more common in the city than in the country.

178. Odors often bring back distant memories.

179. I like to care for animals.

180. A man should spend his leisure time at home with his family.

181. If I had the money, I would enjoy owning an expensive stereo s[illegible].

182. I feel a great attraction to the sea.

183. I would rather sleep on the open ground than in a tent.

184. Given enough time, science will solve most human problems.

Appendix IV: Items from the Family Environment Scale - Form R (Moos and Moos, 1986).

Answer **True** or **False** to the following questions:

1. Family members really help and support one another.
2. Family members often keep their feelings to themselves.
3. We fight a lot in our family.
4. We don't do things on our own very often in our family.
5. We feel it is important to be the best at whatever you do.
6. We often talk about political and social problems.
7. We spend most weekends and evenings at home.
8. Family members attend church, synagogue, or Sunday School fairly often.
9. Activities in our family are pretty carefully planned.
10. Family members are rarely ordered around.
11. We often seem to be killing time at home.
12. We say anything we want to around home.
13. Family members rarely become openly angry.
14. In our family we are strongly encouraged to be independent.
15. Getting ahead in life is very important in our family.
16. We rarely go to lectures, plays or concerts.
17. Friends often come over for dinner or to visit.
18. We don't say prayers in our family.

19. We are generally very neat and orderly.
20. There are very few rules to follow in our family.
21. We put a lot of energy into what we do at home.
22. It's hard to "blow off steam" at home without upsetting somebody.
23. Family members sometimes get so angry they throw things.
24. We think things out for ourselves in our family.
25. How much money a person makes is not very important to us.
26. Learning about new and different things is very important in our family.
27. Nobody in our family is active in sports, Little League, bowling, etc.
28. We often talk about the religious meaning of Christmas, Passover, or other holidays.
29. It's often hard to find things when you need them in our household.
30. There is one family member who makes most of the decisions.
31. There is a feeling of togetherness in our family.
32. We tell each other about our personal problems.
33. Family members hardly ever lose their tempers.
34. We come and go as we want to in our family.
35. We believe in competition and "may the best man win."
36. We are not that interested in cultural activities.

37. We often go to movies, sports events, camping, etc.
38. We don't believe in heaven or hell.
39. Being on time is very important in our family.
40. There are set ways of doing things at home.
41. We rarely volunteer when something has to be done at home.
42. If we feel like doing something on the spur of the moment we often just pick up and go.
43. Family members often criticize each other.
44. There is very little privacy in our family.
45. We always strive to do things just a little better the next time.
46. We rarely have intellectual discussions.
47. Everyone in our family has a hobby or two.
48. Family members have strict ideas about what is right and wrong.
49. People change their minds often in our family.
50. There is a strong emphasis on following rules in our family.
51. Family members really back each other up.
52. Someone usually gets upset if you complain in our family.
53. Family members sometimes hit each other.
54. Family members almost always rely on themselves when a problem comes up.

55. Family members rarely worry about job promotions, school grades, etc.

56. Someone in our family plays a musical instrument.

57. Family members are not very involved in recreational activities outside work or school.

58. We believe there are some things you just have to take on faith.

59. Family members make sure their rooms are neat.

60. Everyone has an equal say in family decisions.

61. There is very little group spirit in our family.

62. Money and paying bills is openly talked about in our family.

63. If there's a disagreement in our family, we try hard to smooth things over and keep the peace.

64. Family members strongly encourage each other to stand up for their rights.

65. In our family we don't try that hard to succeed.

66. Family members often go to the library.

67. Family members sometimes attend courses or take lessons for some hobby or interest (outside of school).

68. In our family each person has different ideas about what is right and wrong.

69. Each person's duties are clearly defined in our family.

70. We can do whatever we want to in our family.

71. We really get along well with each other.

72. We are usually careful about what we say to each other.

73. Family members often try to one-up or out-do each other.

74. It's hard to be by yourself without hurting someone's feelings in our household.

75. "Work before play" is the rule in our family.

76. Watching T.V. is more important than reading in our family.

77. Family members go out a lot.

78. The Bible is a very important book in our home.

79. Money is not handled very carefully in our family.

80. Rules are pretty inflexible in our household.

81. There is plenty of time and attention for everyone in our family.

82. There are a lot of spontaneous discussions in our family.

83. In our family, we believe you don't ever get anywhere by raising your voice.

84. We are not really encouraged to speak up for ourselves in our family.

85. Family members are often compared with others as to how well they are doing at work or school.

86. Family members really like music, art and literature.

87. Our main form of entertainment is watching T.V. or listening to the radio.

88. Family members believe that if you sin you will be punished.

89. Dishes are usually done immediately after eating.

90. You can't get away with much in our family.

APPENDIX V: Items from the Classroom Environment Scale - Form R (Trickett and Moos, 1974).

Answer **True** or **False** to the following questions:

1. Students put a lot of energy into what they do here.
2. Students in this class get to know each other really well.
3. This teacher spends very little time just talking with students.
4. Almost all class time is spent on the lesson for the day.
5. Students don't feel pressured to compete here.
6. This is a well-organized class.
7. There is a clear set of rules for students to follow.
8. There are very few rules to follow.
9. New ideas are always being tried out here.
10. Students daydream a lot in this class.
11. Students in this class aren't very interested in getting to know other students.
12. The teacher takes a personal interest in students.
13. Students are expected to stick to classwork in this class.
14. Students try hard to get the best grade.
15. Students are almost always quiet in this class.
16. Rules in this class seem to change a lot.

17. If a student breaks a rule in this class, he's sure to get in trouble.
18. What students do in class is very different on different days.
19. Students are often "clock-watching" in this class.
20. A lot of friendships have been made in this class.
21. The teacher is more like a friend than an authority.
22. We often spend more time discussing outside student activities than class-related material.
23. Some students always try to see who can answer questions first.
24. Students fool around a lot in this class.
25. The teacher explains what will happen if a student breaks a rule.
26. The teacher is not very strict.
27. New and different ways of teaching are not tried very often in this class.
28. Most students in this class really pay attention to what the teacher is saying.
29. It's easy to get a group together for a project.
30. The teacher goes out of his way to help students.
31. Getting a certain amount of classwork done is very important in this class.
32. Students don't compete with each other here.
33. This class is often in an uproar.
34. The teacher explains what the rules are.

35. Students can get in trouble with the teacher for talking when they're not supposed to.

36. The teacher likes students to try unusual projects.

37. Very few students take part in class discussions or activities.

38. Students enjoy working together on projects in this class.

39. Sometimes the teacher embarrasses students for not knowing the right answer.

40. Students don't do much work in this class.

41. A student's grade is lowered if he gets homework in late.

42. The teacher hardly every has to tell students to get back in their seats.

43. The teacher makes a point of sticking to the rules he's made.

44. Students don't always have to stick to the rules in this class.

45. Students have very little to say about how class time is spent.

46. A lot of students "doodle" or pass notes.

47. Students enjoy helping each other with homework.

48. This teacher "talks down" to students.

49. We usually do as much as we set out to do.

50. Grades are not very important in this class.

51. The teacher often has to tell students to calm down.

52. Whether or not students can get away with something depends on how the teacher is feeling that day.

53. Students get in trouble if they're not in their seats when the class is supposed to start.

54. The teacher thinks up unusual projects for students to do.

55. Students sometimes present something they've worked on to the class.

56. Students don't have much of a chance to get to know each other in this class.

57. If students want to talk about something this teacher will find time to do it.

58. If a student misses a class for a couple of days, it takes some effort to catch up.

59. Students here don't care about what grades the other students are getting.

60. Assignments are usually clear so everyone knows what to do.

61. There are set ways of working on things.

62. It's easier to get into trouble here than in a lot of other classes.

63. Students are expected to follow set rules in doing their work.

64. A lot of students seem to be only half awake during this class.

65. It takes a long time to get to know everybody by his

first name in this class.

66. This teacher wants to know what students themselves want to learn about.

67. This teacher often takes time out from the lesson plan to talk about other things.

68. Students have to work for a good grade in this class.

69. This class hardly every starts on time.

70. In the first few weeks the teacher explained the rules about what students could and could not do in this class.

71. The teacher will put up with a good deal.

72. Students can choose where they sit.

73. Students sometimes do extra work on their own in the class.

74. There are groups of students who don't get along in class.

75. This teacher does not trust students.

76. This class is more a social hour than a place to learn something.

77. Sometimes the class breaks up into groups to compete with each other.

78. Activities in this class are clearly and carefully planned.

79. Students aren't always sure if something is against the rules or not.

80. The teacher will kick a student out of class if he acts

up.

81. Students do the same kind of homework almost every day.

82. Students really enjoy this class.

83. Some students in this class don't like each other.

84. Students have to watch what they say in this class.

85. The teacher sticks to classwork and doesn't get sidetracked.

86. Students usually pass even if they don't do much.

87. Students don't interrupt the teacher when he's talking.

88. The teacher is consistent in dealing with students who break the rules.

89. When the teacher makes a rule, he means it.

90. In this class, students are allowed to make up their own projects.

APPENDIX VI: Sample LISREL Script For The Full ACE Model

```
MZ DATA: FULL ACE MODEL: PRF variables: AB
da ng=2 ni=44 no=89 ma=cm
la
ab1 ac1 af1 ag1 au1 ch1 cs1 de1 do1 en1 ex1
ha1 im1 nu1 or1 pl1 se1 sr1 su1 un1 in1 dy1
ab2 ac2 af2 ag2 au2 ch2 cs2 de2 do2 en2 ex2
ha2 im2 nu2 or2 pl2 se2 sr2 su2 un2 in2 dy2
cm fi=c:\thesis\stats\mzprf.cmx re
select
ab1 ab2/
mo ny=2 ne=2 nk=6 ly=id ga=fu,fr ph=sy,fi ps=ze te=ze
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
st 1.0 ph(2,5) ph(3,6)
lk
*
'e1' 'a1' 'c1' 'e2' 'a2' 'c2'
le
'p1' 'p2'
pa ga
1 1 1 0 0 0
0 0 0 1 1 1
eq ga(1,1) ga(2,4)
eq ga(1,2) ga(2,5)
eq ga(1,3) ga(2,6)
st .20 ga(1,1)-ga(2,6)
ou ns ad=off tm=120 ss sc it=100
DZ TWIN DATA: FULL ACE MODEL: ab
da ni=44 no=49  ma=cm
la
ab1 ac1 af1 ag1 au1 ch1 cs1 de1 do1 en1 ex1
ha1 im1 nu1 or1 pl1 se1 sr1 su1 un1 in1 dy1
ab2 ac2 af2 ag2 au2 ch2 cs2 de2 do2 en2 ex2
ha2 im2 nu2 or2 pl2 se2 sr2 su2 un2 in2 dy2
cm fi=c:\thesis\stats\dzprf.cmx re
select
ab1 ab2 /
mo ly=in ga=in ph=sy,fi ps=in te=in
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
ph(3,6)
st .50 ph(5,2)
lk
*
'e1' 'a1' 'c1' 'e2' 'a2' 'c2'
le
'p1' 'p2'
ou ns ad=off tm=120 ss sc it=100
```

APPENDIX VII: Sample LISREL Script For The Full ADE Model

```
MZ DATA: FULL ADE MODEL: PRF variables: ch
da ng=2 ni=44 no=89 ma=cm
la
ab1 ac1 af1 ag1 au1 ch1 cs1 de1 do1 en1 ex1
ha1 im1 nu1 or1 pl1 se1 sr1 su1 un1 in1 dy1
ab2 ac2 af2 ag2 au2 ch2 cs2 de2 do2 en2 ex2
ha2 im2 nu2 or2 pl2 se2 sr2 su2 un2 in2 dy2
cm fi=c:\thesis\stats\mzprf.cmx re
select
ch1 ch2/
mo ny=2 ne=2 nk=6 ly=id ga=fu,fr ph=sy,fi ps=ze te=ze
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
st 1.0 ph(2,5) ph(3,6)
lk
*
'e1' 'a1' 'd1' 'e2' 'a2' 'ds'
le
'p1' 'p2'
pa ga
1 1 1 0 0 0
0 0 0 1 1 1
eq ga(1,1) ga(2,4)
eq ga(1,2) ga(2,5)
eq ga(1,3) ga(2,6)
st .20 ga(1,1)-ga(2,6)
ou ns ad=off tm=120 ss sc it=100
DZ TWIN DATA: FULL ADE MODEL: ch
da ni=44 no=49  ma=cm
la
ab1 ac1 af1 ag1 au1 ch1 cs1 de1 do1 en1 ex1
ha1 im1 nu1 or1 pl1 se1 sr1 su1 un1 in1 dy1
ab2 ac2 af2 ag2 au2 ch2 cs2 de2 do2 en2 ex2
ha2 im2 nu2 or2 pl2 se2 sr2 su2 un2 in2 dy2
cm fi=c:\thesis\stats\dzprf.cmx re
select
ch1 ch2 /
mo ly=in ga=in ph=sy,fi ps=in te=in
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
ph(3,6)
st .25 ph(5,2)
lk
*
'e1' 'a1' 'd1' 'e2' 'a2' 'ds'
le
'p1' 'p2'
ou ns ad=off tm=120 ss sc it=100
```

Appendix VIII: Sample LISREL Script For The A Multivariate Biometric Model

```
Biometric common factor model: 2 FACTORS
da ng=2 ni=78 no=91 ma=cm
la
*
'AB1' 'AC1' 'AF1' 'AG1' 'AU1' 'CH1' 'CS1' 'DE1'
'DO1' 'EN1' 'EX1' 'HA1' 'IM1' 'NU1' 'OR1' 'PL1' 'SE1' 'SR1'
'SU1' 'UN1'
'IN1' 'DY1'
'AB2' 'AC2' 'AF2' 'AG2' 'AU2' 'CH2' 'CS2' 'DE2'
'DO2' 'EN2' 'EX2' 'HA2' 'IM2' 'NU2' 'OR2' 'PL2' 'SE2' 'SR2'
'SU2' 'UN2'
'IN2' 'DY2' 'L1' 'F1' 'K1' 'HS1' 'D1' 'HY1' 'PD1' 'MF1'
'PA1' 'PT1'
'SC1' 'MA1' 'SI1' 'A1' 'R1' 'ES1' 'MAC1'
'L2' 'F2' 'K2' 'HS2' 'D2' 'HY2' 'PD2' 'MF2'
'PA2' 'PT2' 'SC2' 'MA2' 'SI2' 'A2' 'R2' 'ES2' 'MAC2'
select
DY1 K1 DY2 K2 /
cm fi=c:\thesis\stats\mzp.cmx re
mo ny=4 ne=4 nk=18 ga=fu,fr ly=fu,fi ph=sy,fi ps=ze te=ze
lk
*
'a1' 'c1' 'e1'
'a2' 'c2' 'e2'
'aa' 'cc' 'ee'
'aa:tw2' 'cc:tw2' 'ee:tw2'
'a1:tw2' 'c1:tw2' 'e1:tw2'
'a2:tw2' 'c2:tw2' 'e2:tw2'
le
*
'p1' 'p2' 'p3'
'p1:tw2' 'p2:tw2' 'p3:tw2'
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
ph(7,7)
st 1.0 ph(8,8) ph(9,9) ph(10,10) ph(11,11) ph(12,12)
ph(13,13)
st 1.0 ph(14,14) ph(15,15) ph(16,16) ph(17,17) ph(18,18)
st 1.0 ph(1,13) ph(4,16)
st 1.0 ph(2,14) ph(5,17)
st 1.0 ph(7,10) ph(8,11)
st 1.0 ly(1,1) ly(2,2) ly(3,3) ly(4,4)
pa ga
(18I1)
111000111000000000
000111111000000000
000000000111111000
000000000111000111
eq ga(1,1) ga(3,13)
```

```
eq ga(1,2) ga(3,14)
eq ga(1,3) ga(3,15)
eq ga(2,4) ga(4,16)
eq ga(2,5) ga(4,17)
eq ga(2,6) ga(4,18)
eq ga(1,7) ga(3,10)
eq ga(1,8) ga(3,11)
eq ga(1,9) ga(3,12)
eq ga(2,7) ga(4,10)
eq ga(2,8) ga(4,11)
eq ga(2,9) ga(4,12)
st  20 ga(1,1)
st .20 ga(1,2)
st .20 ga(1,3)
st .20 ga(2,4)
st .20 ga(2,5)
st .20 ga(2,6)
st .20 ga(1,7)
st .20 ga(1,8)
st .20 ga(1,9)
st .20 ga(2,7)
st .20 ga(2,8)
st .20 ga(2,9)
ou ns tm=2400 ss sc ad=off it=200
Biometric common factor multivariate model: DZs: 2 factor
model
da ng=2 ni=78 no=91 ma=cm
la
*
'AB1' 'AC1' 'AF1' 'AG1' 'AU1' 'CH1' 'CS1' 'DE1'
'DO1' 'EN1' 'EX1' 'HA1' 'IM1' 'NU1' 'OR1' 'PL1' 'SE1' 'SR1'
'SU1' 'UN1'
'IN1' 'DY1'
'AB2' 'AC2' 'AF2' 'AG2' 'AU2' 'CH2' 'CS2' 'DE2'
'DO2' 'EN2' 'EX2' 'HA2' 'IM2' 'NU2' 'OR2' 'PL2' 'SE2' 'SR2'
'SU2' 'UN2'
'IN2' 'DY2' 'L1' 'F1' 'K1' 'HS1' 'D1' 'HY1' 'PD1' 'MF1'
'PA1' 'PT1'
'SC1' 'MA1' 'SI1' 'A1' 'R1' 'ES1' 'MAC1'
'L2' 'F2' 'K2' 'HS2' 'D2' 'HY2' 'PD2' 'MF2'
'PA2' 'PT2' 'SC2' 'MA2' 'SI2' 'A2' 'R2' 'ES2' 'MAC2'
select
DY1 K1 DY2 K2 /
cm fi=c:\thesis\stats\dzp.cmx re
mo ny=4 ne=4 nk=18 ga=in ly=fu,fi ph=sy,fi ps=ze te=ze
lk
*
'a1' 'c1' 'e1'
'a2' 'c2' 'e2'
'aa' 'cc' 'ee'
'aa:tw2' 'cc:tw2' 'ee:tw2'
'a1:tw2' 'c1:tw2' 'e1:tw2'
```

```
'a2:tw2' 'c2:tw2' 'e2:tw2'
le
*
'p1' 'p2' 'p3'
'p1:tw2' 'p2:tw2' 'p3:tw2'
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
ph(7,7)
st 1.0 ph(8,8) ph(9,9) ph(10,10) ph(11,11) ph(12,12)
ph(13,13)
st 1.0 ph(14,14) ph(15,15) ph(16,16) ph(17,17) ph(18,18)
st .50 ph(1,13) ph(4,16)
st 1.0 ph(2,14) ph(5,17)
st .50 ph(7,10)
st 1.0 ph(8,11)
st 1.0 ly(1,1) ly(2,2) ly(3,3) ly(4,4)
ou ns tm=2400 ss sc ad=off it=200
```

APPENDIX IX: Sample LISREL Output For A Simple ACE Model

```
1                            386 - L I S R E L  7.20
0                                       BY
0                         KARL G JORESKOG AND DAG SORBOM


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                         1525 East 53rd Street, Suite 906
                          Chicago, Illinois 60615, U.S.A.
                           (800)247-6113 or (312)684-4979
```



```
OTHE FOLLOWING LISREL CONTROL LINES HAVE BEEN READ :


 MZ TWINS: FULL MODEL: PRF variables: AB
 da ng=2 ni=44 no=89 ma=cm
 la
 ab1 ac1 af1 ag1 au1 ch1 cs1 de1 do1 en1 ex1
 ha1 im1 nu1 or1 pl1 se1 sr1 su1 un1 in1 dy1
 ab2 ac2 af2 ag2 au2 ch2 cs2 de2 do2 en2 ex2
 ha2 im2 nu2 or2 pl2 se2 sr2 su2 un2 in2 dy2
 cm fi=c:\thesis\stats\mzprf.cmx re
 select
 ab1 ab2/
 mo ny=2 ne=2 nk=6 ly=id ga=fu,fr ph=sy,fi ps=ze te=ze
 st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6)
 st 1.0 ph(2,5) ph(3,6)
 lk
 *
 'e1' 'a1' 'c1' 'e2' 'a2' 'c2'
 le
 'p1' 'p2'
 pa ga
 1 1 1 0 0 0
 0 0 0 1 1 1
 eq ga(1,1) ga(2,4)
 eq ga(1,2) ga(2,5)
 eq ga(1,3) ga(2,6)
 st .20 ga(1,1)-ga(2,6)
 ou ns ad=off tm=120 ss sc it=100
1MZ TWINS: FULL MODEL: PRF variables: AB
0                           NUMBER OF INPUT VARIABLES 44
0                           NUMBER OF Y - VARIABLES    2
0                           NUMBER OF X - VARIABLES    0
0                           NUMBER OF ETA - VARIABLES  2
0                           NUMBER OF KSI - VARIABLES  6
0                           NUMBER OF OBSERVATIONS    89
0                           NUMBER OF GROUPS           2
1MZ TWINS: FULL MODEL: PRF variables: AB
0        COVARIANCE MATRIX TO BE ANALYZED
0                ab1         ab2
+             --------    --------
      ab1       0.966
      ab2       0.330      0.977
1                            386 - L I S R E L  7.20
0                                       BY
0                         KARL G JORESKOG AND DAG SORBOM


OTHE FOLLOWING LISREL CONTROL LINES HAVE BEEN READ :
```

```
DZ TWINS: FULL MODEL: ab
da ni=44 no=49  ma=cm
la
ab1 ac1 af1 ag1 au1 ch1 cs1 de1 do1 en1 ex1
ha1 im1 nu1 or1 pl1 se1 sr1 su1 un1 in1 dy1
ab2 ac2 af2 ag2 au2 ch2 cs2 de2 do2 en2 ex2
ha2 im2 nu2 or2 pl2 se2 sr2 su2 un2 in2 dy2
cm fi=c:\thesis\stats\dzprf.cmx re
select
ab1 ab2 /
mo ly=in ga=in ph=sy,fi ps=in te=in
st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6) ph(3,6)
st .50 ph(5,2)
lk
*
'e1' 'a1' 'c1' 'e2' 'a2' 'c2'
le
'p1' 'p2'
ou ns ad=off tm=120 ss sc it=100
1DZ TWINS: FULL MODEL: ab
0                            NUMBER OF INPUT VARIABLES 44
0                            NUMBER OF Y - VARIABLES    2
0                            NUMBER OF X - VARIABLES    0
0                            NUMBER OF ETA - VARIABLES  2
0                            NUMBER OF KSI - VARIABLES  6
0                            NUMBER OF OBSERVATIONS    49
0                            NUMBER OF GROUPS           2
1DZ TWINS: FULL MODEL: ab
0         COVARIANCE MATRIX TO BE ANALYZED
0                 ab1         ab2
+              --------    --------
      ab1       0.958
      ab2       0.303       0.958
1MZ TWINS: FULL MODEL: PRF variables: AB
OPARAMETER SPECIFICATIONS
0         GAMMA
0                 e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
       p1           1           2           3           0           0           0
       p2           0           0           0           1           2           3
0         PHI
0                 e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
       e1           0
       a1           0           0
       c1           0           0           0
       e2           0           0           0           0
       a2           0           0           0           0           0
       c2           0           0           0           0           0           0
1DZ TWINS: FULL MODEL: ab
OPARAMETER SPECIFICATIONS
0         GAMMA
0                 e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
       p1           1           2           3           0           0           0
       p2           0           0           0           1           2           3
0         PHI
0                 e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
       e1           0
       a1           0           0
       c1           0           0           0
       e2           0           0           0           0
       a2           0           0           0           0           0
       c2           0           0           0           0           0           0
1MZ TWINS: FULL MODEL: PRF variables: AB
OSTARTING VALUES
0         GAMMA
0                 e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
       p1       0.200       0.200       0.200       0.000       0.000       0.000
       p2       0.000       0.000       0.000       0.200       0.200       0.200
0         COVARIANCE MATRIX OF ETA AND KSI
```

```
0                 p1          p2          e1          a1          c1          e2
+             ________    ________    ________    ________    ________    ________
       p1      0.120
       p2      0.080       0.120
       e1      0.200       0.000       1.000
       a1      0.200       0.200       0.000       1.000
       c1      0.200       0.200       0.000       0.000       1.000
       e2      0.000       0.200       0.000       0.000       0.000       1.000
       a2      0.200       0.200       0.000       1.000       0.000       0.000
       c2      0.200       0.200       0.000       0.000       1.000       0.000
0         COVARIANCE MATRIX OF ETA AND KSI
0                 a2          c2
+             ________    ________
       a2      1.000
       c2      0.000       1.000
1DZ TWINS: FULL MODEL: ab
0STARTING VALUES
0         GAMMA
0                 e1          a1          c1          e2          a2          c2
+             ________    ________    ________    ________    ________    ________
       p1      0.200       0.200       0.200       0.000       0.000       0.000
       p2      0.000       0.000       0.000       0.200       0.200       0.200
0         COVARIANCE MATRIX OF ETA AND KSI
0                 p1          p2          e1          a1          c1          e2
+             ________    ________    ________    ________    ________    ________
       p1      0.120
       p2      0.060       0.120
       e1      0.200       0.000       1.000
       a1      0.200       0.100       0.000       1.000
       c1      0.200       0.200       0.000       0.000       1.000
       e2      0.000       0.200       0.000       0.000       0.000       1.000
       a2      0.100       0.200       0.000       0.500       0.000       0.000
       c2      0.200       0.200       0.000       0.000       1.000       0.000
0         COVARIANCE MATRIX OF ETA AND KSI
0                 -2          c2
+             ________    ________
       a2      1.000
       c2      0.000       1.000
1MZ TWINS: FULL MODEL: PRF var ables: AB
0LISREL ESTIMATES (MAXIMUM LIKELIHOOD)
0         GAMMA
0                 e1          a1          c1          e2          a2          c2
+             ________    ________    ________    ________    ________    ________
       p1     -0.800       0.191       0.539       0.000       0.000       0.000
       p2      0.000       0.000       0.000      -0.800       0.191       0.539
0         COVARIANCE MATRIX OF ETA AND KSI
0                 p1          p2          e1          a1          c1          e2
+             ________    ________    ________    ________    ________    ________
       p1      0.967
       p2      0.327       0.967
       e1     -0.800       0.000       1 000
       a1      0.191       0.191       0.000       1.000
       c1      0.539       0.539       0.000       0.000       1.000
       e2      0.000      -0.800       0.000       0.000       0.000       1.000
       a2      0.191       0.191       0.000       1.000       0.000       0.000
       c2      0.539       0.539       0.000       0.000       1.000       0.000
0         COVARIANCE MATRIX OF ETA AND KSI
0                 a2          c2
+             ________    ________
       a2      1.000
       c2      0.000       1.000
0W_A_R_N_I_N_G : PHI is not positive definite


0                         GOODNESS OF FIT INDEX =1.000
                     ROOT MEAN SQUARE RESIDUAL =      0.006
1MZ TWINS: FULL MODEL: PRF variables: AB
-SUMMARY STATISTICS FOR FITTED RESIDUALS
 SMALLEST FITTED RESIDUAL =   -0.001
   MEDIAN FITTED RESIDUAL =    0.003
  LARGEST FITTED RESIDUAL =    0.010
-STEMLEAF PLOT
 - 0|1
```

```
   0|3
   0|
   1|0
-SUMMARY STATISTICS FOR STANDARDIZED RESIDUALS
 SMALLEST STANDARDIZED RESIDUAL =   -0.018
   MEDIAN STANDARDIZED RESIDUAL =    0.068
  LARGEST STANDARDIZED RESIDUAL =    0.184
-STEMLEAF PLOT
 - 0|2
   0|
   0|7
   1|
   1|8
1MZ TWINS: FULL MODEL: PRF variables: AB
-WITHIN GROUP STANDARDIZED SOLUTION
0         GAMMA
0                  e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
        p1       -0.814       0.194       0.548       0.000       0.000       0.000
        p2        0.000       0.000       0.000      -0.814       0.194       0.548
0         CORRELATION MATRIX OF ETA AND KSI
0                  p1          p2          e1          a1          c1          e2
+              --------    --------    --------    --------    --------    --------
        p1        1.000
        p2        0.338       1.000
        e1       -0.814       0.000       1.000
        a1        0.194       0.194       0.000       1.000
        c1        0.548       0.548       0.000       0.000       1.000
        e2        0.000      -0.814       0.000       0.000       0.000       1.000
        a2        0.194       0.194       0.000       1.000       0.000       0.000
        c2        0.548       0.548       0.000       0.000       1.000       0.000
0         CORRELATION MATRIX OF ETA AND KSI
0                  a2          c2
+              --------    --------
        a2        1.000
        c2        0.000       1.000
1MZ TWINS: FULL MODEL: PRF variables: AB
-WITHIN GROUP COMPLETELY STANDARDIZED SOLUTION
0         GAMMA
0                  e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
        p1       -0.814       0.194       0.548       0.000       0.000       0.000
        p2        0.000       0.000       0.000      -0.814       0.194       0.548
0         CORRELATION MATRIX OF ETA AND KSI
0                  p1          p2          e1          a1          c1          e2
+              --------    --------    --------    --------    --------    --------
        p1        1.000
        p2        0.338       1.000
        e1       -0.814       0.000       1.000
        a1        0.194       0.194       0.000       1.000
        c1        0.548       0.548       0.000       0.000       1.000
        e2        0.000      -0.814       0.000       0.000       0.000       1.000
        a2        0.194       0.194       0.000       1.000       0.000       0.000
        c2        0.548       0.548       0.000       0.000       1.000       0.000
0         CORRELATION MATRIX OF ETA AND KSI
0                  a2          c2
+              --------    --------
        a2        1.000
        c2        0.000       1.000
1DZ TWINS: FULL MODEL: ab
OLISREL ESTIMATES (MAXIMUM LIKELIHOOD)
0         GAMMA
0                  e1          a1          c1          e2          a2          c2
+              --------    --------    --------    --------    --------    --------
        p1       -0.800       0.191       0.539       0.000       0.000       0.000
        p2        0.000       0.000       0.000      -0.800       0.191       0.539
0         COVARIANCE MATRIX OF ETA AND KSI
0                  p1          p2          e1          a1          c1          e2
+              --------    --------    --------    --------    --------    --------
        p1        0.967
        p2        0.308       0.967
        e1       -0.800       0.000       1.000
        a1        0.191       0.095       0.000       1.000
```

```
        c1       0.539      0.539      0.000      0.000      1.000
        e2       0.000     -0.800      0.000      0.000      0.000      1.000
        a2       0.095      0.191      0.000      0.500      0.000      0.000
        c2       0.539      0.539      0.000      0.000      1.000      0.000
0         COVARIANCE MA.RIX OF ETA AND KSI
0                   a2         c2
+              --------   --------
        a2       1.000
        c2       0.000      1.000
0W_A_R_N_I_N_G : PHI is not positive definite


0          CHI-SQUARE WITH   3 DEGREES OF FREEDOM =     0.01 (P = 1.00)
0                        GOODNESS OF FIT INDEX =1.000
                     ROOT MEAN SQUARE RESIDUAL =     0.008
1DZ TWINS: FULL MODEL: ab
-SUMMARY STATISTICS FOR FITTED RESIDUALS
 SMALLEST FITTED RESIDUAL =   -0.009
   MEDIAN FITTED RESIDUAL =   -0.009
  LARGEST FITTED RESIDUAL =   -0.005
-STEMLEAF PLOT
 - 8|55
 - 7|
 - 6|
 - 5|
 - 4|9
-SUMMARY STATISTICS FOR STANDARDIZED RESIDUALS
 SMALLEST STANDARDIZED RESIDUAL =   -0.112
   MEDIAN STANDARDIZED RESIDUAL =   -0.112
  LARGEST STANDARDIZED RESIDUAL =   -0.087
-STEMLEAF PLOT
 -11|22
 -10|
 -10|
 - 9|
 - 9|
 - 8|7
1DZ TWINS: FULL MODEL: ab
-WITHIN GROUP STANDARDIZED SOLUTION
0         GAMMA
0                   e1         a1         c1         e2         a2         c2
+              --------   --------   --------   --------   --------   --------
        p1      -0.814      0.194      0.548      0.000      0.000      0.000
        p2       0.000      0.000      0.000     -0.814      0.194      0.548
0         CORRELATION MATRIX OF ETA AND KSI
0                   p1         p2         e1         a1         c1         e2
+              --------   --------   --------   --------   --------   --------
        p1       1.000
        p2       0.319      1.000
        e1      -0.814      0.000      1.000
        a1       0.194      0.097      0.000      1.000
        c1       0.548      0.548      0.000      0.000      1.000
        e2       0.000     -0.814      0.000      0.000      0.000      1.000
        a2       0.097      0.194      0.000      0.500      0.000      0.000
        c2       0.548      0.548      0.000      0.000      1.000      0.000
0         CORRELATION MATRIX OF ETA AND KSI
0                   a2         c2
+              --------   --------
        a2       1.000
        c2       0.000      1.000
1DZ TWINS: FULL MODEL: ab
-WITHIN GROUP COMPLETELY STANDARDIZED SOLUTION
0         G..MA
0                   e1         a1         c1         e2         a2         c2
+              --------   --------   --------   --------   --------   --------
        p1      -0.814      0.194      0.548      0.000      0.000      0.000
        p2       0.000      0.000      0.000     -0.814      0.194      0.548
0         CORRELATION MATRIX OF ETA AND KSI
0                   p1         p2         e1         a1         c1         e2
+              --------   --------   --------   --------   --------   --------
        p1       1.000
        p2       0.319      1.000
        e1      -0.814      0.000      1.000
```

a1	0.194	0.097	0.000	1.000		
c1	0.548	0.548	0.000	0.000	1.000	
e2	0.000	-0.814	0.000	0.000	0.000	1.000
a2	0.097	0.194	0.000	0.500	0.000	0.000
c2	0.548	0.548	0.000	0.000	1.000	0.000

0 CORRELATION MATRIX OF ETA AND KSI

	a2	c2
a2	1.000	
c2	0.000	1.000

1MZ TWINS: FULL MODEL: PRF variables: AB

-COMMON METRIC STANDARDIZED SOLUTION

0 GAMMA

	e1	a1	c1	e2	a2	c2
p1	-0.814	0.194	0.548	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.814	0.194	0.548

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	e1	a1	c1	e2
p1	1.000					
p2	0.338	1.000				
e1	-0.814	0.000	1.000			
a1	0.194	0.194	0.000	1.000		
c1	0.548	0.548	0.000	0.000	1.000	
e2	0.000	-0.814	0.000	0.000	0.000	1.000
a2	0.194	0.194	0.000	1.000	0.000	0.000
c2	0.548	0.548	0.000	0.000	1.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	a2	c2
a2	1.000	
c2	0.000	1.000

1MZ TWINS: FULL MODEL: PRF variables: AB

-COMMON METRIC COMPLETELY STANDARDIZED SOLUTION

0 GAMMA

	e1	a1	c1	e2	a2	c2
p1	-0.814	0.194	0.548	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.814	0.194	0.548

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	e1	a1	c1	e2
p1	1.000					
p2	0.338	1.000				
e1	-0.814	0.000	1.000			
a1	0.194	0.194	0.000	1.000		
c1	0.548	0.548	0.000	0.000	1.000	
e2	0.000	-0.814	0.000	0.000	0.000	1.000
a2	0.194	0.194	0.000	1.000	0.000	0.000
c2	0.548	0.548	0.000	0.000	1.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	a2	c2
a2	1.000	
c2	0.000	1.000

1DZ TWINS: FULL MODEL: ab

-COMMON METRIC STANDARDIZED SOLUTION

0 GAMMA

	e1	a1	c1	e2	a2	c2
p1	-0.814	0.194	0.548	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.814	0.194	0.548

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	e1	a1	c1	e2
p1	1.000					
p2	0.319	1.000				
e1	-0.814	0.000	1.000			
a1	0.194	0.097	0.000	1.000		
c1	0.548	0.548	0.000	0.000	1.000	
e2	0.000	-0.814	0.000	0.000	0.000	1.000
a2	0.097	0.194	0.000	0.500	0.000	0.000

```
        c2      0.548      0.548      0.000      0.000      1.000      0.000
0         COVARIANCE MATRIX OF ETA AND KSI
0                  a2         c2
+             --------   --------
        a2      1.000
        c2      0.000      1.000
1DZ TWINS: FULL MODEL: ab
-COMMON METRIC COMPLETELY STANDARDIZED SOLUTION
0         GAMMA
0                  e1         a1         c1         e2         a2         c2
+             --------   --------   --------   --------   --------   --------
        p1     -0.814      0.194      0.548      0.000      0.000      0.000
        p2      0.000      0.000      0.000     -0.814      0.194      0.548
0         COVARIANCE MATRIX OF ETA AND KSI
0                  p1         p2         e1         a1         c1         e2
+             --------   --------   --------   --------   --------   --------
        p1      1.000
        p2      0.319      1.000
        e1     -0.814      0.000      1.000
        a1      0.194      0.097      0.000      1.000
        c1      0.548      0.548      0.000      0.000      1.000
        e2      0.000     -0.814      0.000      0.000      0.000      1.000
        a2      0.097      0.194      0.000      0.500      0.000      0.000
        c2      0.548      0.548      0.000      0.000      1.000      0.000
0         COVARIANCE MATRIX OF ETA AND KSI
0                  a2         c2
+             --------   --------
        a2      1.000
        c2      0.000      1.000
-          THE PROBLEM USED     5096 BYTES (=  1.9% OF AVAILABLE WORKSPACE)
-                            TIME USED :     5.6 SECONDS
```

APPENDIX X: Sample LISREL Output For A Two Factor Multivariate Biometric Model

```
1                           386 - L I S R E L  7.20
0                                     BY
0                         KARL G JORESKOG AND DAG SORBOM


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```



```
OTHE FOLLOWING LISREL CONTROL LINES HAVE BEEN READ :


 Biometric common factor multivariate model: 2 FACTORS
 da ng=2 ni=78 no=91 ma=cm
 la
 *
 'AB1' 'AC1' 'AF ' 'AG1' 'AU1' 'CH1' 'CS1' 'DE1'
 'DO1' 'EN1' 'EX  'HA1' 'IM1' 'NU1' 'OR1' 'PL1' 'SE1' 'SR1' 'SU1' 'UN1'
 'IN1' 'DY1'
 'AB2' 'AC2' 'AF2' 'AG2' 'AU2' 'CH2' 'CS2' 'DE2'
 'DO2' 'EN2' 'EX2' 'HA2' 'IM2' 'NU2' 'OR2' 'PL2' 'SE2' 'SR2' 'SU2' 'UN2'
 'IN2' 'DY2' 'L1' 'F1' 'K1' 'HS1' 'D1' 'HY1' 'PD1' 'MF1' 'PA1' 'PT1'
 'SC1' 'MA1' 'SI1' 'A1' 'R1' 'ES1' 'MAC1'
 'L2' 'F2' 'K2' 'HS2' 'D2' 'HY2' 'PD2' 'MF2'
 'PA2' 'PT2' 'SC2' 'MA2' 'SI2' 'A2' 'R2' 'ES2' 'MAC2'
 select
 DY1 K1 DY2 K2 /
 cm fi=c:\thesis\stats\mzp.cmx re
 mo ny=4 ne=4 nk=18 ga=fu,fr ly=fu,fi ph=sy,fi ps=ze te=ze
 lk
 *
 'a1' 'c1' 'e1'
 'a2' 'c2' 'e2'
 'aa' 'cc' 'ee'
 'aa:tw2' 'cc:tw2' 'ee:tw2'
 'a1:tw2' 'c1:tw2' 'e1:tw2'
 'a2:tw2' 'c2:tw2' 'e2:tw2'
 le
 *
 'p1' 'p2' 'p3'
 'p1:tw2' 'p2:tw2' 'p3:tw2'
 st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6) ph(7,7)
 st 1.0 ph(8,8) ph(9,9) ph(10,10) ph(11,11) ph(12,12) ph(13,13)
 st 1.0 ph(14,14) ph(15,15) ph(16,16) ph(17,17) ph(18,18)
 st 1.0 ph(1,13) ph(4,16)
 st 1.0 ph(2,14) ph(5,17)
 st 1.0 ph(7,10) ph(8,11)
 st 1.0 ly(1,1) ly(2,2) ly(3,3) ly(4,4)
 pa ga
 (18I1)
 eq ga(1,1) ga(3,13)
 eq ga(1,2) ga(3,14)
 eq ga(1,3) ga(3,15)
 eq ga(2,4) ga(4,16)
 eq ga(2,5) ga(4,17)
 eq ga(2,6) ga(4,18)
 eq ga(1,7) ga(3,10)
 eq ga(1,8) ga(3,11)
 eq ga(1,9) ga(3,12)
 eq ga(2,7) ga(4,10)
```

```
 eq ga(2,8) ga(4,11)
 eq ga(2,9) ga(4,12)
 st .20 ga(1,1)
 st .20 ga(1,2)
 st .20 ga(1,3)
 st .20 ga(2,4)
 st .20 ga(2,5)
 st .20 ga(2,6)
 st .20 ga(1,7)
 st .20 ga(1,8)
 st .20 ga(1,9)
 st .20 ga(2,7)
 st .20 ga(2,8)
 st .20 ga(2,9)
 ou ns tm=2400 ss sc ad=off it=200
1Biometric common factor multivariate model: 2 FACTORS
0                          NUMBER OF INPUT VARIABLES 78
0                          NUMBER OF Y - VARIABLES    4
0                          NUMBER OF X - VARIABLES    0
0                          NUMBER OF ETA - VARIABLES  4
0                          NUMBER OF KSI - VARIABLES 18
0                          NUMBER OF OBSERVATIONS    91
0                          NUMBER OF GROUPS           2
1Biometric common factor multivariate model: 2 FACTORS
0        COVARIANCE MATRIX TO BE ANALYZED
0                 DY1          K1         DY2          K2
+              --------    --------    --------    --------
     DY1        0.977
      K1        0.360       0.876
     DY2        0.523       0.268       0.966
      K2        0.288       0.532       0.444       0.875
1                              386 - L I S R E L  7.20
0                                        BY
0                            KARL G JORESKOG AND DAG SORBOM


OTHE FOLLOWING LISREL CONTROL LINES HAVE BEEN READ :


 Biometric common factor multivariate model: DZ 2 factor model
 da ng=2 ni=78 no=91 ma=cm
 la
 *
 'AB1' 'AC1' 'AF1' 'AG1' 'AU1' 'CH1' 'CS1' 'DE1'
 'DO1' 'EN1' 'EX1' 'HA1' 'IM1' 'NU1' 'OR1' 'PL1' 'SE1' 'SR1' 'SU1' 'UN1'
 'IN1' 'DY1'
 'AB2' 'AC2' 'AF2' 'AG2' 'AU2' 'CH2' 'CS2' 'DE2'
 'DO2' 'EN2' 'EX2' 'HA2' 'IM2' 'NU2' 'OR2' 'PL2' 'SE2' 'SR2' 'SU2' 'UN2'
 'IN2' 'DY2' 'L1' 'F1' 'K1' 'HS1' 'D1' 'HY1' 'PD1' 'MF1' 'PA1' 'PT1'
 'SC1' 'MA1' 'SI1' 'A1' 'R1' 'ES1' 'MAC1'
 'L2' 'F2' 'K2' 'HS2' 'D2' 'HY2' 'PD2' 'MF2'
 'PA2' 'PT2' 'SC2' 'MA2' 'SI2' 'A2' 'R2' 'ES2' 'MAC2'
 select
 DY1 K1 DY2 K2 /
 cm fi=c:\thesis\stats\dzp.cmx re
 mo ny=4 ne=4 nk=18 ga=in ly=fu,fi ph=sy,fi ps=ze te=ze
 lk
 *
 'a1' 'c1' 'e1'
 'a2' 'c2' 'e2'
 'aa' 'cc' 'ee'
 'aa:tw2' 'cc:tw2' 'ee:tw2'
 'a1:tw2' 'c1:tw2' 'e1:tw2'
 'a2:tw2' 'c2:tw2' 'e2:tw2'
 le
 *
 'p1' 'p2' 'p3'
 'p1:tw2' 'p2:tw2' 'p3:tw2'
 st 1.0 ph(1,1) ph(2,2) ph(3,3) ph(4,4) ph(5,5) ph(6,6) ph(7,7)
 st 1.0 ph(8,8) ph(9,9) ph(10,10) ph(11,11) ph(12,12) ph(13,13)
 st 1.0 ph(14,14) ph(15,15) ph(16,16) ph(17,17) ph(18,18)
 st .50 ph(1,13) ph(4,16)
 st 1.0 ph(2,14) ph(5,17)
```

```
 st .50 ph(7,10)
 st 1.0 ph(8,11)
 st 1.0 ly(1,1) ly(2,2) ly(3,3) ly(4,4)
 ou ns tm=2400 ss sc ad=off it=200
1Biometric common factor multivariate model: DZ 2 factor model
0                         NUMBER OF INPUT VARIABLES 78
0                         NUMBER OF Y - VARIABLES    4
0                         NUMBER OF X - VARIABLES    0
0                         NUMBER OF ETA - VARIABLES  4
0                         NUMBER OF KSI - VARIABLES 18
0                         NUMBER OF OBSERVATIONS    91
0                         NUMBER OF GROUPS           2
1Biometric common factor multivariate model: DZ 2 factor model
0        COVARIANCE MATRIX TO BE ANALYZED
0                DY1         K1        DY2         K2
+           --------   --------   --------   --------
     DY1       0.958
      K1       0.410      0.879
     DY2       0.471      0.247      0.958
      K2       0.077     -0.114      0.248      0.884
1Biometric common factor multivariate model: 2 FACTORS
0PARAMETER SPECIFICATIONS
0        LAMBDA Y
0                 p1         p2         p3      p1:tw2
+           --------   --------   --------   --------
     DY1           0          0          0          0
      K1           0          0          0          0
     DY2           0          0          0          0
      K2           0          0          0          0
0        GAMMA
0                 a1         c1         e1         a2         c2         e2
+           --------   --------   --------   --------   --------   --------
      p1           1          2          3          0          0          0
      p2           0          0          0          7          8          9
      p3           0          0          0          0          0          0
  p1:tw2           0          0          0          0          0          0
0        GAMMA
0                 aa         cc         ee     aa:tw2     cc:tw2     ee:tw2
+           --------   --------   --------   --------   --------   --------
      p1           4          5          6          0          0          0
      p2          10         11         12          0          0          0
      p3           0          0          0          4          5          6
  p1:tw2           0          0          0         10         11         12
0        GAMMA
0             a1:tw2     c1:tw2     e1:tw2     a2:tw2     c2:tw2     e2:tw2
+           --------   --------   --------   --------   --------   --------
      p1           0          0          0          0          0          0
      p2           0          0          0          0          0          0
      p3           1          2          3          0          0          0
  p1:tw2           0          0          0          7          8          9
0        PHI
0                 a1         c1         e1         a2         c2         e2
+           --------   --------   --------   --------   --------   --------
      a1           0
      c1           0          0
      e1           0          0          0
      a2           0          0          0          0
      c2           0          0          0          0          0
      e2           0          0          0          0          0          0
      aa           0          0          0          0          0          0
      cc           0          0          0          0          0          0
      ee           0          0          0          0          0          0
  aa:tw2           0          0          0          0          0          0
  cc:tw2           0          0          0          0          0          0
  ee:tw2           0          0          0          0          0          0
  a1:tw2           0          0          0          0          0          0
  c1:tw2           0          0          0          0          0          0
  e1:tw2           0          0          0          0          0          0
  a2:tw2           0          0          0          0          0          0
  c2:tw2           0          0          0          0          0          0
  e2:tw2           0          0          0          0          0          0
0        PHI
0                 aa         cc         ee     aa:tw2     cc:tw2     ee:tw2
```

```
+
        aa    ________  ________  ________  ________  ________  ________
                     0
        cc           0         0
        ee           0         0         0
     aa:tw2          0         0         0         0
     cc:tw2          0         0         0         0         0
     ee:tw2          0         0         0         0         0         0
     a1:tw2          0         0         0         0         0         0
     c1:tw2          0         0         0         0         0         0
     e1:tw2          0         0         0         0         0         0
     a2:tw2          0         0         0         0         0         0
     c2:tw2          0         0         0         0         0         0
     e2:tw2          0         0         0         0         0         0
0         PHI
0               a1:tw2    c1:tw2    e1:tw2    a2:tw2    c2:tw2    e2:tw2
+
              ________  ________  ________  ________  ________  ________
     a1:tw2          0
     c1:tw2          0         0
     e1:tw2          0         0         0
     a2:tw2          0         0         0         0
     c2:tw2          0         0         0         0         0
     e2:tw2          0         0         0         0         0         0
1Biometric common factor multivariate model: DZ 2 factor model
0PARAMETER SPECIFICATIONS
0         LAMBDA Y
0                   p1        p2        p3    p1:tw2
+
              ________  ________  ________  ________
       DY1           0         0         0         0
        K1           0         0         0         0
       DY2           0         0         0         0
        K2           0         0         0         0
0         GAMMA
0                   a1        c1        e1        a2        c2        e2
+
              ________  ________  ________  ________  ________  ________
        p1           1         2         3         0         0         0
        p2           0         0         0         7         8         9
        p3           0         0         0         0         0         0
    p1:tw2           0         0         0         0         0         0
0         GAMMA
0                   aa        cc        ee    aa:tw2    cc:tw2    ee:tw2
+
              ________  ________  ________  ________  ________  ________
        p1           4         5         6         0         0         0
        p2          10        11        12         0         0         0
        p3           0         0         0         4         5         6
    p1:tw2           0         0         0        10        11        12
0         GAMMA
0               a1:tw2    c1:tw2    e1:tw2    a2:tw2    c2:tw2    e2:tw2
+
              ________  ________  ________  ________  ________  ________
        p1           0         0         0         0         0         0
        p2           0         0         0         0         0         0
        p3           1         2         3         0         0         0
    p1:tw2           0         0         0         7         8         9
0         PHI
0                   a1        c1        e1        a2        c2        e2
+
              ________  ________  ________  ________  ________  ________
        a1           0
        c1           0         0
        e1           0         0         0
        a2           0         0         0         0
        c2           0         0         0         0         0
        e2           0         0         0         0         0         0
        aa           0         0         0         0         0         0
        cc           0         0         0         0         0         0
        ee           0         0         0         0         0         0
    aa:tw2           0         0         0         0         0         0
    cc:tw2           0         0         0         0         0         0
    ee:tw2           0         0         0         0         0         0
    a1:tw2           0         0         0         0         0         0
    c1:tw2           0         0         0         0         0         0
    e1:tw2           0         0         0         0         0         0
    a2:tw2           0         0         0         0         0         0
    c2:tw2           0         0         0         0         0         0
    e2:tw2           0         0         0         0         0         0
```

0 PHI

0

+

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
aa	0					
cc	0	0				
ee	0	0	0			
aa:tw2	0	0	0	0		
cc:tw2	0	0	0	0	0	
ee:tw2	0	0	0	0	0	0
a1:tw2	0	0	0	0	0	0
c1:tw2	0	0	0	0	0	0
e1:tw2	0	0	0	0	0	0
a2:tw2	0	0	0	0	0	0
c2:tw2	0	0	0	0	0	0
e2:tw2	0	0	0	0	0	0

0 PHI

0

+

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
a1:tw2	0					
c1:tw2	0	0				
e1:tw2	0	0	0			
a2:tw2	0	0	0	0		
c2:tw2	0	0	0	0	0	
e2:tw2	0	0	0	0	0	0

1Biometric common factor multivariate model: 2 FACTORS

0STARTING VALUES

0 LAMBDA Y

0

+

	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0 GAMMA

0

+

	a1	c1	e1	a2	c2	e2
p1	0.200	0.200	0.200	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.200	0.200	0.200
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

0

+

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.200	0.200	0.200	0.000	0.000	0.000
p2	0.200	0.200	0.200	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.200	0.200	0.200
p1:tw2	0.000	0.000	0.000	0.200	0.200	0.200

0 GAMMA

0

+

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	0.200	0.200	0.200	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.200	0.200	0.200

0 COVARIANCE MATRIX OF ETA AND KSI

0

+

	p1	p2	p3	p1:tw2	a1	c1
p1	0.240					
p2	0.120	0.240				
p3	0.160	0.080	0.240			
p1:tw2	0.080	0.160	0.120	0.240		
a1	0.200	0.000	0.200	0.000	1.000	
c1	0.200	0.000	0.200	0.000	0.000	1.000
e1	0.200	0.000	0.000	0.000	0.000	0.000
a2	0.000	0.200	0.000	0.200	0.000	0.000
c2	0.000	0.200	0.000	0.200	0.000	0.000
e2	0.000	0.200	0.000	0.000	0.000	0.000
aa	0.200	0.200	0.200	0.200	0.000	0.000
cc	0.200	0.200	0.200	0.200	0.000	0.000
ee	0.200	0.200	0.000	0.000	0.000	0.000
aa:tw2	0.200	0.200	0.200	0.200	0.000	0.000
cc:tw2	0.200	0.200	0.200	0.200	0.000	0.000
ee:tw2	0.000	0.000	0.200	0.200	0.000	0.000

a1:tw2	0.200	0.000	0.200	0.000	1.000	0.000
c1:tw2	0.200	0.000	0.200	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.200	0.000	0.000	0.000
a2:tw2	0.000	0.200	0.000	0.200	0.000	0.000
c2:tw2	0.000	0.200	0.000	0.200	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.200	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

0	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	1.000	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	1.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

0	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

0	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: DZ 2 factor model

0STARTING VALUES

0 LAMBDA Y

0	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0 GAMMA

0	a1	c1	e1	a2	c2	e2
p1	0.200	0.200	0.200	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.200	0.200	0.200
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

0	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.200	0.200	0.200	0.000	0.000	0.000
p2	0.200	0.200	0.200	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.200	0.200	0.200
p1:tw2	0.000	0.000	0.000	0.200	0.200	0.200

0 GAMMA

0	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000

p3	0.200	0.200	0.200	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.200	0.200	0.200

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	0.240					
p2	0.120	0.240				
p3	0.120	0.060	0.240			
p1:tw2	0.060	0.120	0.120	0.240		
a1	0.200	0.000	0.100	0.000	1.000	
c1	0.200	0.000	0.200	0.000	0.000	1.000
e1	0.200	0.000	0.000	0.000	0.000	0.000
a2	0.000	0.200	0.000	0.100	0.000	0.000
c2	0.000	0.200	0.000	0.200	0.000	0.000
e2	0.000	0.200	0.000	0.000	0.000	0.000
aa	0.200	0.200	0.100	0.100	0.000	0.000
cc	0.200	0.200	0.200	0.200	0.000	0.000
ee	0.200	0.200	0.000	0.000	0.000	0.000
aa:tw2	0.100	0.100	0.200	0.200	0.000	0.000
cc:tw2	0.200	0.200	0.200	0.200	0.000	0.000
ee:tw2	0.000	0.000	0.200	0.200	0.000	0.000
a1:tw2	0.100	0.000	0.200	0.000	0.500	0.000
c1:tw2	0.200	0.000	0.200	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.200	0.000	0.000	0.000
a2:tw2	0.000	0.100	0.000	0.200	0.000	0.000
c2:tw2	0.000	0.200	0.000	0.200	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.200	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	0.500	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.500	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: 2 FACTORS

0LISREL ESTIMATES (MAXIMUM LIKELIHOOD)

0 LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000

DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0
GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.144	0.000	-0.576	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.377	0.000	-0.595
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0
GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.234	0.663	-0.344	0.000	0.000	0.000
p2	0.500	0.213	-0.318	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.234	0.663	-0.344
p1:tw2	0.000	0.000	0.000	0.500	0.213	-0.318

0
GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.144	0.000	-0.576	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.377	0.000	-0.595

0
COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	0.965					
p2	0.368	0.892				
p3	0.515	0.258	0.965			
p1:tw2	0.258	0.437	0.368	0.892		
a1	-0.144	0.000	-0.144	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.576	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.377	0.000	-0.377	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.595	0.000	0.000	0.000	0.000
aa	0.234	0.500	0.234	0.500	0.000	0.000
cc	0.663	0.213	0.663	0.213	0.000	0.000
ee	-0.344	-0.318	0.000	0.000	0.000	0.000
aa:tw2	0.234	0.500	0.234	0.500	0.000	0.000
cc:tw2	0.663	0.213	0.663	0.213	0.000	0.000
ee:tw2	0.000	0.000	-0.344	-0.318	0.000	0.000
a1:tw2	-0.144	0.000	-0.144	0.000	1.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.576	0.000	0.000	0.000
a2:tw2	0.000	-0.377	0.000	-0.377	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.595	0.000	0.000

0
COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	1.000	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	1.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0
COVARIANCE MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			

```
   ee:tw2      0.000       0.000       0.000       1.000
   a1:tw2      0.000       0.000       0.000       0.000       1.000
   c1:tw2      0.000       0.000       0.000       0.000       0.000       1.000
   e1:tw2      0.000       0.000       0.000       0.000       0.000       0.000
   a2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
   c2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
   e2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
0         COVARIANCE MATRIX OF ETA AND KSI
0             e1:tw2      a2:tw2      c2:tw2      e2:tw2
+          --------    --------    --------    --------
   e1:tw2      1.000
   a2:tw2      0.000       1.000
   c2:tw2      0.000       0.000       1.000
   e2:tw2      0.000       0.000       0.000       1.000
0W_A_R_N_I_N_G : PHI is not positive definite


0                           GOODNESS OF FIT INDEX =0.972
                        ROOT MEAN SQUARE RESIDUAL =     0.041
1Biometric common factor multivariate model: 2 FACTORS
-SUMMARY STATISTICS FOR FITTED RESIDUALS
 SMALLEST FITTED RESIDUAL =    -0.016
   MEDIAN FITTED RESIDUAL =     0.009
  LARGEST FITTED RESIDUAL =     0.095
-STEMLEAF PLOT
 - 0|2210
   0|1113
   0|8
   1|0
0W_A_R_N_I_N_G :  GA 1,2 may not be identified. Standard error estimates,
                  T-values, Modification Indices and Standardized residuals
                  cannot be computed.
1Biometric common factor multivariate model: 2 FACTORS
-WITHIN GROUP STANDARDIZED SOLUTION
0         LAMBDA Y
0                 p1          p2          p3      p1:tw2
+          --------    --------    --------    --------
      DY1      0.982       0.000       0.000       0.000
       K1      0.000       0.944       0.000       0.000
      DY2      0.000       0.000       0.982       0.000
       K2      0.000       0.000       0.000       0.944
0         GAMMA
0                 a1          c1          e1          a2          c2          e2
+          --------    --------    --------    --------    --------    --------
       p1     -0.147       0.000      -0.586       0.000       0.000       0.000
       p2      0.000       0.000       0.000      -0.399       0.000      -0.630
       p3      0.000       0.000       0.000       0.000       0.000       0.000
   p1:tw2      0.000       0.000       0.000       0.000       0.000       0.000
0         GAMMA
0                 aa          cc          ee      aa:tw2      cc:tw2      ee:tw2
+          --------    --------    --------    --------    --------    --------
       p1      0.238       0.675      -0.350       0.000       0.000       0.000
       p2      0.529       0.226      -0.337       0.000       0.000       0.000
       p3      0.000       0.000       0.000       0.238       0.675      -0.350
   p1:tw2      0.000       0.000       0.000       0.529       0.226      -0.337
0         GAMMA
0             a1:tw2      c1:tw2      e1:tw2      a2:tw2      c2:tw2      e2:tw2
+          --------    --------    --------    --------    --------    --------
       p1      0.000       0.000       0.000       0.000       0.000       0.000
       p2      0.000       0.000       0.000       0.000       0.000       0.000
       p3     -0.147       0.000      -0.586       0.000       0.000       0.000
   p1:tw2      0.000       0.000       0.000      -0.399       0.000      -0.630
0         CORRELATION MATRIX OF ETA AND KSI
0                 p1          p2          p3      p1:tw2          a1          c1
+          --------    --------    --------    --------    --------    --------
       p1      1.000
       p2      0.396       1.000
       p3      0.534       0.278       1.000
   p1:tw2      0.278       0.490       0.396       1.000
       a1     -0.147       0.000      -0.147       0.000       1.000
       c1      0.000       0.000       0.000       0.000       0.000       1.000
       e1     -0.586       0.000       0.000       0.000       0.000       0.000
       a2      0.000      -0.399       0.000      -0.399       0.000       0.000
```

c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.238	0.529	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.238	0.529	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.147	0.000	-0.147	0.000	1.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.399	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	1.000	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	1.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

Biometric common factor multivariate model: 2 FACTORS

WITHIN GROUP COMPLETELY STANDARDIZED SOLUTION

LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.147	0.000	-0.586	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.399	0.000	-0.630
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.238	0.675	-0.350	0.000	0.000	0.000

p2	0.529	0.226	-0.337	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.238	0.675	-0.350
p1:tw2	0.000	0.000	0.000	0.529	0.226	-0.337

GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.147	0.000	-0.586	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.399	0.000	-0.630

CORRELATION MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.534	0.278	1.000			
p1:tw2	0.278	0.490	0.396	1.000		
a1	-0.147	0.000	-0.147	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.399	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.238	0.529	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.238	0.529	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.147	0.000	-0.147	0.000	1.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.399	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	1.000	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	1.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	

e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: DZ 2 factor model
OLISREL ESTIMATES (MAXIMUM LIKEL'HOOD)
0 LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0 GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.144	0.000	-0.576	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.377	0.000	-0.595
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.234	0.663	-0.344	0.000	0.000	0.000
p2	0.500	0.213	-0.318	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.234	0.663	-0.344
p1:tw2	0.000	0.000	0.000	0.500	0.213	-0.318

0 GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.144	0.000	-0.576	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.377	0.000	-0.595

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	0.965					
p2	0.368	0.892				
p3	0.478	0.200	0.965			
p1:tw2	0.200	0.241	0.368	0.892		
a1	-0.144	0.000	-0.072	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.576	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.377	0.000	-0.188	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.595	0.000	0.000	0.000	0.000
aa	0.234	0.500	0.117	0.250	0.000	0.000
cc	0.663	0.213	0.663	0.213	0.000	0.000
ee	-0.344	-0.318	0.000	0.000	0.000	0.000
aa:tw2	0.117	0.250	0.234	0.500	0.000	0.000
cc:tw2	0.663	0.213	0.663	0.213	0.000	0.000
ee:tw2	0.000	0.000	-0.344	-0.318	0.000	0.000
a1:tw2	-0.072	0.000	-0.144	0.000	0.500	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.576	0.000	0.000	0.000
a2:tw2	0.000	-0.188	0.000	-0.377	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.595	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	0.500	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.500	0.000	0.000	0.000	0.000

```
   c2:tw2      0.000       0.000       1.000       0.000       0.000       0.000
   e2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
0        COVARIANCE MATRIX OF ETA AND KSI
0                  ee      aa:tw2      cc:tw2      ee:tw2      a1:tw2      c1:tw2
+             --------    --------    --------    --------    --------    --------
       ee      1.000
   aa:tw2      0.000       1.000
   cc:tw2      0.000       0.000       1.000
   ee:tw2      0.000       0.000       0.000       1.000
   a1:tw2      0.000       0.000       0.000       0.000       1.000
   c1:tw2      0.000       0.000       0.000       0.000       0.000       1.000
   e1:tw2      0.000       0.000       0.000       0.000       0.000       0.000
   a2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
   c2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
   e2:tw2      0.000       0.000       0.000       0.000       0.000       0.000
0        COVARIANCE MATRIX OF ETA AND KSI
0              e1:tw2      a2:tw2      c2:tw2      e2:tw2
+             --------    --------    --------    --------
   e1:tw2      1.000
   a2:tw2      0.000       1.000
   c2:tw2      0.000       0.000       1.000
   e2:tw2      0.000       0.000       0.000       1.000
0W_A_R_N_I_N_G : PHI is not positive definite


0         CHI-SQUARE WITH   8 DEGREES OF FREEDOM =     26.51 (P = .001)
0                     GOODNESS OF FIT INDEX =0.891
                 ROOT MEAN SQUARE RESIDUAL =      0.126
1Biometric common factor multivariate model: DZ 2 factor model
-SUMMARY STATISTICS FOR FITTED RESIDUALS
 SMALLEST FITTED RESIDUAL =   -0.355
   MEDIAN FITTED RESIDUAL =   -0.007
  LARGEST FITTED RESIDUAL =    0.048
-STEMLEAF PLOT
 - 3|6
 - 2|
 - 1|22
 - 0|11111
   0|45
0W_A_R_N_I_N_G :  GA 1,2 may not be identified. Standard error estimates,
                  T-values, Modification Indices and Standardized residuals
                  cannot be computed.
1Biometric common factor multivariate model: DZ 2 factor model
-WITHIN GROUP STANDARDIZED SOLUTION
0        LAMBDA Y
0                  p1          p2          p3      p1:tw2
+             --------    --------    --------    --------
      DY1      0.982       0.000       0.000       0.000
       K1      0.000       0.944       0.000       0.000
      DY2      0.000       0.000       0.982       0.000
       K2      0.000       0.000       0.000       0.944
0        GAMMA
0                  a1          c1          e1          a2          c2          e2
+             --------    --------    --------    --------    --------    --------
       p1     -0.147       0.000      -0.586       0.000       0.000       0.000
       p2      0.000       0.000       0.000      -0.399       0.000      -0.630
       p3      0.000       0.000       0.000       0.000       0.000       0.000
   p1:tw2      0.000       0.000       0.000       0.000       0.000       0.000
0        GAMMA
0                  aa          cc          ee      aa:tw2      cc:tw2      ee:tw2
+             --------    --------    --------    --------    --------    --------
       p1      0.238       0.675      -0.350       0.000       0.000       0.000
       p2      0.529       0.226      -0.337       0.000       0.000       0.000
       p3      0.000       0.000       0.000       0.238       0.675      -0.350
   p1:tw2      0.000       0.000       0.000       0.529       0.226      -0.337
0        GAMMA
0              a1:tw2      c1:tw2      e1:tw2      a2:tw2      c2:tw2      e2:tw2
+             --------    --------    --------    --------    --------    --------
       p1      0.000       0.000       0.000       0.000       0.000       0.000
       p2      0.000       0.000       0.000       0.000       0.000       0.000
       p3     -0.147       0.000      -0.586       0.000       0.000       0.000
   p1:tw2      0.000       0.000       0.000      -0.399       0.000      -0.630
0        CORRELATION MATRIX OF ETA AND KSI
```

0

+	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.495	0.215	1.000			
p1:tw2	0.215	0.270	0.396	1.000		
a1	-0.147	0.000	-0.073	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.199	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.119	0.265	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.119	0.265	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.073	0.000	-0.147	0.000	0.500	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.199	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

0 CORRELATION MATRIX OF ETA AND KSI

0

+	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	0.500	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.500	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 CORRELATION MATRIX OF ETA AND KSI

0

+	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 CORRELATION MATRIX OF ETA AND KSI

0

+	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: DZ 2 factor model

-WITHIN GROUP COMPLETELY STANDARDIZED SOLUTION

0 LAMBDA Y

0

+	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0 GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.147	0.000	-0.586	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.399	0.000	-0.630
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.238	0.675	-0.350	0.000	0.000	0.000
p2	0.529	0.226	-0.337	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.238	0.675	-0.350
p1:tw2	0.000	0.000	0.000	0.529	0.226	-0.337

GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.147	0.000	-0.586	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.399	0.000	-0.630

CORRELATION MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.495	0.215	1.000			
p1:tw2	0.215	0.270	0.396	1.000		
a1	-0.147	0.000	-0.073	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.199	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.119	0.265	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.119	0.265	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.073	0.000	-0.147	0.000	0.500	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.199	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	0.500	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.500	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

CORRELATION MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000

e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 CORRELATION MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: 2 FACTORS

-COMMON METRIC STANDARDIZED SOLUTION

0 LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	0.982	0.000	0.000	0.000
K1	0.000	0.944	0.000	0.000
DY2	0.000	0.000	0.982	0.000
K2	0.000	0.000	0.000	0.944

0 GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.147	0.000	-0.586	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.399	0.000	-0.630
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.238	0.675	-0.350	0.000	0.000	0.000
p2	0.529	0.226	-0.337	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.238	0.675	-0.350
p1:tw2	0.000	0.000	0.000	0.529	0.226	-0.337

0 GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.147	0.000	-0.586	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.399	0.000	-0.630

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.537	0.278	1.000			
p1:tw2	0.278	0.490	0.396	1.000		
a1	-0.147	0.000	-0.147	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.399	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.238	0.529	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.238	0.529	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.147	0.000	-0.147	0.000	1.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.399	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		

aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	1.000	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	1.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: 2 FACTORS

-COMMON METRIC COMPLETELY STANDARDIZED SOLUTION

0 LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0 GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.147	0.000	-0.586	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.399	0.000	-0.630
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.238	0.675	-0.350	0.000	0.000	0.000
p2	0.529	0.226	-0.337	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.238	0.675	-0.350
p1:tw2	0.000	0.000	0.000	0.529	0.226	-0.337

0 GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.147	0.000	-0.586	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.399	0.000	-0.630

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.534	0.278	1.000			
p1:tw2	0.278	0.490	0.396	1.000		
a1	-0.147	0.000	-0.147	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.399	0.000	0.000

c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.238	0.529	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.238	0.529	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.147	0.000	-0.147	0.000	1.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.399	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	1.000	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	1.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: DZ 2 factor model

-COMMON METRIC STANDARDIZED SOLUTION

0 LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	0.982	0.000	0.000	0.000
K1	0.000	0.944	0.000	0.000
DY2	0.000	0.000	0.982	0.000
K2	0.000	0.000	0.000	0.944

0 GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.147	0.000	-0.586	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.399	0.000	-0.630
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.238	0.675	-0.350	0.000	0.000	0.000

p2	0.529	0.226	-0.337	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.238	0.675	-0.350
p1:tw2	0.000	0.000	0.000	0.529	0.226	-0.337

0 GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.147	0.000	-0.586	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.399	0.000	-0.630

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.495	0.215	1.000			
p1:tw2	0.215	0.270	0.396	1.000		
a1	-0.147	0.000	-0.073	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.199	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.119	0.265	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.119	0.265	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.073	0.000	-0.147	0.000	0.500	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.199	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	0.500	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.500	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	

e2:tw2	0.000	0.000	0.000	1.000

1Biometric common factor multivariate model: DZ 2 factor model

-COMMON METRIC COMPLETELY STANDARDIZED SOLUTION

0 LAMBDA Y

	p1	p2	p3	p1:tw2
DY1	1.000	0.000	0.000	0.000
K1	0.000	1.000	0.000	0.000
DY2	0.000	0.000	1.000	0.000
K2	0.000	0.000	0.000	1.000

0 GAMMA

	a1	c1	e1	a2	c2	e2
p1	-0.147	0.000	-0.586	0.000	0.000	0.000
p2	0.000	0.000	0.000	-0.399	0.000	-0.630
p3	0.000	0.000	0.000	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 GAMMA

	aa	cc	ee	aa:tw2	cc:tw2	ee:tw2
p1	0.238	0.675	-0.350	0.000	0.000	0.000
p2	0.529	0.226	-0.337	0.000	0.000	0.000
p3	0.000	0.000	0.000	0.238	0.675	-0.350
p1:tw2	0.000	0.000	0.000	0.529	0.226	-0.337

0 GAMMA

	a1:tw2	c1:tw2	e1:tw2	a2:tw2	c2:tw2	e2:tw2
p1	0.000	0.000	0.000	0.000	0.000	0.000
p2	0.000	0.000	0.000	0.000	0.000	0.000
p3	-0.147	0.000	-0.586	0.000	0.000	0.000
p1:tw2	0.000	0.000	0.000	-0.399	0.000	-0.630

0 COVARIANCE MATRIX OF ETA AND KSI

	p1	p2	p3	p1:tw2	a1	c1
p1	1.000					
p2	0.396	1.000				
p3	0.495	0.215	1.000			
p1:tw2	0.215	0.270	0.396	1.000		
a1	-0.147	0.000	-0.073	0.000	1.000	
c1	0.000	0.000	0.000	0.000	0.000	1.000
e1	-0.586	0.000	0.000	0.000	0.000	0.000
a2	0.000	-0.399	0.000	-0.199	0.000	0.000
c2	0.000	0.000	0.000	0.000	0.000	0.000
e2	0.000	-0.630	0.000	0.000	0.000	0.000
aa	0.238	0.529	0.119	0.265	0.000	0.000
cc	0.675	0.226	0.675	0.226	0.000	0.000
ee	-0.350	-0.337	0.000	0.000	0.000	0.000
aa:tw2	0.119	0.265	0.238	0.529	0.000	0.000
cc:tw2	0.675	0.226	0.675	0.226	0.000	0.000
ee:tw2	0.000	0.000	-0.350	-0.337	0.000	0.000
a1:tw2	-0.073	0.000	-0.147	0.000	0.500	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	-0.586	0.000	0.000	0.000
a2:tw2	0.000	-0.199	0.000	-0.399	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	-0.630	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1	a2	c2	e2	aa	cc
e1	1.000					
a2	0.000	1.000				
c2	0.000	0.000	1.000			
e2	0.000	0.000	0.000	1.000		
aa	0.000	0.000	0.000	0.000	1.000	
cc	0.000	0.000	0.000	0.000	0.000	1.000
ee	0.000	0.000	0.000	0.000	0.000	0.000
aa:tw2	0.000	0.000	0.000	0.000	0.500	0.000
cc:tw2	0.000	0.000	0.000	0.000	0.000	1.000
ee:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.500	0.000	0.000	0.000	0.000

c2:tw2	0.000	0.000	1.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	ee	aa:tw2	cc:tw2	ee:tw2	a1:tw2	c1:tw2
ee	1.000					
aa:tw2	0.000	1.000				
cc:tw2	0.000	0.000	1.000			
ee:tw2	0.000	0.000	0.000	1.000		
a1:tw2	0.000	0.000	0.000	0.000	1.000	
c1:tw2	0.000	0.000	0.000	0.000	0.000	1.000
e1:tw2	0.000	0.000	0.000	0.000	0.000	0.000
a2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
c2:tw2	0.000	0.000	0.000	0.000	0.000	0.000
e2:tw2	0.000	0.000	0.000	0.000	0.000	0.000

0 COVARIANCE MATRIX OF ETA AND KSI

	e1:tw2	a2:tw2	c2:tw2	e2:tw2
e1:tw2	1.000			
a2:tw2	0.000	1.000		
c2:tw2	0.000	0.000	1.000	
e2:tw2	0.000	0.000	0.000	1.000

\- THE PROBLEM USED 33568 BYTES (= 12.8% OF AVAILABLE WORKSPACE)

\- TIME USED : 26.4 SECONDS