CHILD PERCEPTION OF PARENTAL BEHAVIOR IN TWINS: A RISK FACTOR FOR SUBSTANCE USE DISORDERS?

by

Lisa M. Moss

BA, St. Olaf College, 2001

Submitted to the Graduate Faculty of

The Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2008

UNIVERSITY OF PITTSBURGH

THE GRADUATE SCHOOL OF PUBLIC HEALTH

This thesis was presented

by

Lisa M. Moss

It was defended on

April 9, 2008

and approved by

Thesis Advisor: Michael M. Vanyukov, Ph.D.
Associate Professor
Department of Pharmaceutical Sciences, School of Pharmacy
Department of Psychiatry, School of Medicine
Department of Human Genetics, Graduate School of Public Health
University of Pittsburgh

Elizabeth A. Gettig, M.S., C.G.C.
Associate Professor
Department of Human Genetics, Graduate School of Public Health
University of Pittsburgh

Mary L. Marazita, Ph.D.
Professor
Department of Oral Biology, School of Dental Medicine
Department of Human Genetics, Graduate School of Public Health
Department of Psychiatry, School of Medicine
University of Pittsburgh

CHILD PERCEPTION OF PARENTAL BEHAVIORS IN TWINS: A RISK FACTOR FOR SUBSTANCE USE DISORDERS?

Lisa M. Moss, M.S.

University of Pittsburgh, 2008

The risk to develop a substance use disorder (SUD) is a significant public health concern, particularly as it relates to prevention and intervention strategies. Elucidation of the possible precursors to SUD is an objective of this study. The main purpose of this research was to evaluate the relationship between the child's perception of parental behavior and his/her risk for SUD as measured by an index of transmissible liability (TLI). Previous research points to a relationship between parental behavior and behavior problems in the child, which includes substance use disorders. Additionally, much of this research suggests the presence of genetic effects contributing to the individual variation in these traits. Participants were self-selected twin pairs and at least one parent attending the Twins Days Festival (Twinsburg, OH) in 2006 and 2007. Biometrical genetic analysis was applied to the sample of twin pairs on a measure of parental behavior perception (PB) and the TLI. Results of the research indicate that children's perception of parental behavior is associated with liability for substance use disorders. It was found that the variation in parental behavior perception is due to shared and unique environmental effects, whereas the TLI has a high heritability ($h^2 = 0.79$). The study also validates the liability index as a measure of transmissible risk for substance use disorders as well as provides support for the PB scale as a measure of an aspect of the child's environment.

TABLE OF CONTENTS

PREFACE ..... **IX**

1.0 INTRODUCTION **1**

1.1 SPECIFIC AIMS **2**

1.1.1 Aim 1: **2**

1.1.2 Aim 2: **3**

1.1.3 Aim 3: **3**

2.0 PITTSBURGH REGISTRY OF INFANT MULTIPLETS **4**

3.0 BACKGROUND AND SIGNIFICANCE **8**

3.1 THE TWIN METHOD **8**

3.1.1 Biometrical Genetics: Twin Method **10**

3.2 PERCEPTION OF PARENTAL BEHAVIOR **15**

3.2.1 Effects of Parent Behavior on the Child **16**

3.2.2 Measurement of Parent Behavior Perception **19**

3.2.3 Genetics **21**

3.3 LIABILITY TO SUBSTANCE USE DISORDERS **24**

4.0 METHODS **29**

4.1 SAMPLE POPULATION **29**

4.2 ZYGOSITY DETERMINATION **30**

4.3 CHILDREN'S REPORT ON PARENTAL BEHAVIOR INVENTORY 30

4.4 SUD TRANSMISSIBLE LIABILITY INDEX 31

4.5 STATISTICAL ANALYSES 33

4.5.1 Standard Statistics 33

4.5.2 Reliability Assessment 33

4.5.3 Correlation and Regression Analyses 34

4.5.4 Structural Equation Modeling 34

5.0 RESULTS 37

5.1 SAMPLE STATISTICS 37

5.2 PB AND LI 38

5.3 STRUCTURAL EQUATION MODELING 42

5.4 THE RELATIONSHIP BETWEEN PARENTING AND LIABILITY INDEX . 43

6.0 DISCUSSION 45

7.0 CONCLUSIONS 52

7.1 PUBLIC HEALTH SIGNIFICANCE 53

APPENDIX A. ZYGOSITY QUESTIONNAIRE 55

APPENDIX B. CHILDREN'S REPORT ON PARENTAL BEHAVIOR INVENTORY (REVISED-PB)..... 59

APPENDIX C. LIABILITY INDEX 61

BIBLIOGRAPHY 66

LIST OF TABLES

Table 1. Zygosity and Sex Cross-tabulation of Twin Pairs 37

Table 2. PB Raw Score Descriptive Statistics 38

Table 3. LI Raw Score Descriptive Statistics 39

Table 4. Correlations Between CRPBI and LI..... 39

Table 5. Comparison of Correlation Coefficients..... 39

Table 6. Overall PB and LI Correlations by Zygosity 40

Table 7. Intrapair Average LI and PB Correlations..... 41

Table 8. Mother and Father PB Correlations in Sons and Daughters..... 41

Table 9. Univariate Model Fitting 42

Table 10. Univariate Modeling Results: Best Fitting Model..... 43

Table 11. Path Model Correlations Between LI and PB for Mothers and Fathers 44

LIST OF FIGURES

Figure 1. PRIM Enrollment by Multiplet Type 6

Figure 2. Monthly PRIM Enrollment by Multiplet Type 7

Figure 3. Twin model univariate path diagram..... 13

Figure 4. Threshold Model for Complex Traits..... 27

PREFACE

I would like to thank the faculty and staff of the Human Genetics department for their help and support. A special thanks to the staff at CEDAR and Maureen Reynolds, Brion Maher, Levent Kirisci, and Zhongcui Gao, for their help collecting data and answering many questions along the way! Thank you to the staff of the Magee-Womens Hospital WomanCare Birth Center for their cooperation with PRIM recruitment efforts.

I would like to express my utmost gratitude to Dr. Michael Vanyukov. I am grateful for your support, guidance, and unending patience.

Thank you to Dr. Mary Marazita for your support of the twin registry and taking time from your busy schedule to serve on this thesis committee.

Thanks to Betsy Gettig and Robin Grubs - you both work so hard to provide us with the best genetic counseling degree and I am grateful to have been able to learn from you both. Thanks for sharing your infinite knowledge and supporting us throughout these 2 years. I hope I can enter the workforce as the counselor you have trained me to be and can continue to advance this profession.

To my classmates, thanks for a memorable 2 years! Thanks for helping to keep me on track, keeping me laughing, and calming me down when my anxiety ran a bit high. I wish you all the best of luck in your upcoming adventures!

To my family and friends, your unending support and faith keep me going every day!

1.0 INTRODUCTION

Parent-child relationships, and the child's perception of those relationships, are important in the behavioral development of the child. These interactions are associated with behavior problems in the child. In particular, parenting has been shown to be related to the risk for childhood behavior disorders as well as substance use disorders. Genetic studies have found that covariation between liabilities to behavior disorders at age 10–12 years is explained by shared environmental influences, and parent–child conflict accounts for a significant proportion of this shared variance (Burt *et al.*, 2001). Conflict or other characteristics of dissatisfaction between parents and children are likely to be reflective of the psychological phenotypes of both parents and children and related to other facets of behavior, such as parenting style. Because of the differences in maternal and paternal roles and in their perception by the child, associations between parenting and child behavior may depend on the parent's sex.

One obvious source of correlations between parenting and child behavior is the direct and, possibly, reciprocal influence of parental behavior of the child's behavior. The complexity of the parent-child interaction is aggravated, however, by the possible phenotype/genotype-environment correlations. In particular, child behavior's contributing to parenting style may induce evocative genotype-environment correlations, whereas genetic contribution to variation in the parental behavior that forms parenting may result in passive genotype-environment correlations (Plomin *et al.*, 1977; Scarr & McCartney, 1983). These correlations may be

augmented by parental behavior's being influenced by the parents' own behavioral characteristics that are the same as the children's heritable traits (e.g., aggressivity, activity) contributing to, e.g., suboptimal interaction. In turn, genetic effects common to such traits may originate from genetic polymorphisms related to behavior as well as drug abuse risk in the central nervous system (Vanyukov *et al.*, 2003b). It is, therefore, important to determine the source of and the relationships between the childhood behavior, the risk for substance use disorders (SUD), and the child perception of parental behavior. Nevertheless, these relationships have not been paid sufficient attention in behavior genetic research (Rutter & Silberg, 2002).

1.1 SPECIFIC AIMS

The following aims were pursued in this study (University of Pittsburgh IRB #PRO07100339) accomplished.

1.1.1 Aim 1:

To expand and maintain a twin registry for future use with research studies. Particularly relevant to the present work is the opportunity to use the registry participants for future longitudinal research on the topic of liability to substance use disorders.

1.1.2 Aim 2:

To evaluate the relationship of the child's perception of paternal and maternal parenting with liability to substance use disorders (SUD).

Hypothesis 1.1: Negatively characterized parenting is related to elevated risk for SUD.

Hypothesis 1.2: Paternal and maternal parenting differentially affects liability to SUD.

Hypothesis 1.3: There is positive assortative mating for parenting style.

1.1.3 Aim 3:

To evaluate the heritability of and genetic correlations between parenting and the liability to substance use disorders.

Hypothesis 2.1: The child's perception of parental behavior and the risk for substance use disorders as measured by a quantitative liability index have significant heritability.

Hypothesis 2.2: The measures of parenting and SUD risk are significantly genetically correlated.

2.0 PITTSBURGH REGISTRY OF INFANT MULTIPLETS

The Pittsburgh Registry of Infant Multiplets (IRB #0410086) is a voluntary registry of multiplets established in 1996. The purpose of the registry is to serve as a resource for qualified researchers applying biometrical genetic methodology in studies of human development. Participation in the registry provides families with up to date information about open research opportunities. Enrollment into the registry is offered to all parents of twins and higher order multiples born at Magee-Womens Hospital of UPMC in Pittsburgh, Pennsylvania. This nationally ranked hospital serves much of western Pennsylvania and delivers 45% of the babies born in Allegheny County (Magee-Womens Hospital, 2008).

It is the goal of the coordinator for the Pittsburgh Registry of Infant Multiplets (PRIM), to invite all parents of multiples born at Magee-Womens Hospital to participate. The first step is to identify eligible mothers. After the birth of their babies, mothers are taken to one of three post-partum units at the hospital. An identification and congratulatory tag is placed outside of the mother's room. The tags are pink for female newborns, or blue for males. A multiple birth will have the corresponding number of tags of the appropriate colors outside the door. Once a mother of multiples has been identified, permission to speak with her is obtained by a unit nurse or other healthcare provider. If the mother agrees to meet, the PRIM coordinator explains the registry and what her participation will involve. If she decides to participate, she signs the informed consent and HIPAA forms. Additionally, a brief questionnaire is completed to gather

information about the babies' weights, APGAR scores, delivery date, length of gestation, pregnancy/delivery complications, parent's birthdays, race, and contact information. For interested parents, a newsletter for the North Pittsburgh Mothers of Multiples (NPMOMs) group is distributed. Parents choosing to enroll in the registry are classified as "joined." Those declining to speak with the coordinator or declining participation after learning about the registry are classified as "decliners." "Missed," describes those mothers identified as being eligible for participation but unavailable for invitation. Having babies in the neonatal intensive care unit (NICU) is the most common reason for being missed, as the parents spend most of their time in the NICU and not in the post-partum room.

Families joining the registry receive a welcome letter in the mail. The information gathered on the questionnaire is entered into a Microsoft Access database with each family receiving a unique registry identification number. Researchers interested in contacting families for participation in studies must submit the protocol to the PRIM Principal Investigator, Michael Vanyukov, for approval. Study descriptions are then mailed to eligible families on behalf of the researcher. Participation in research studies is voluntary.

To date, 735 families have enrolled in the PRIM, which includes multiplets ranging in age from newborns to age 14. Enrollment from September 2006 - March 2008 was 118 multiplets comprised 34% female/female twin pairs, 37% male/female pairs, 25% male/male pairs, and 4% triplets (see Figures 1 and 2). The rate of families classified as either "missed" or "declined" was 27% during this time period. A primary goal of the PRIM coordinator is to develop recruitment strategies to reduce the rate of missed and declined families. An additional aim of the coordinator is to develop a communication method (e.g. mail, email) to maintain contact with and obtain updated information about participating families. Thus far, efforts have

been focused on updating mailing addresses of participants. Once the registry has been updated, the feasibility and effectiveness of various communication methods will be assessed and implemented.

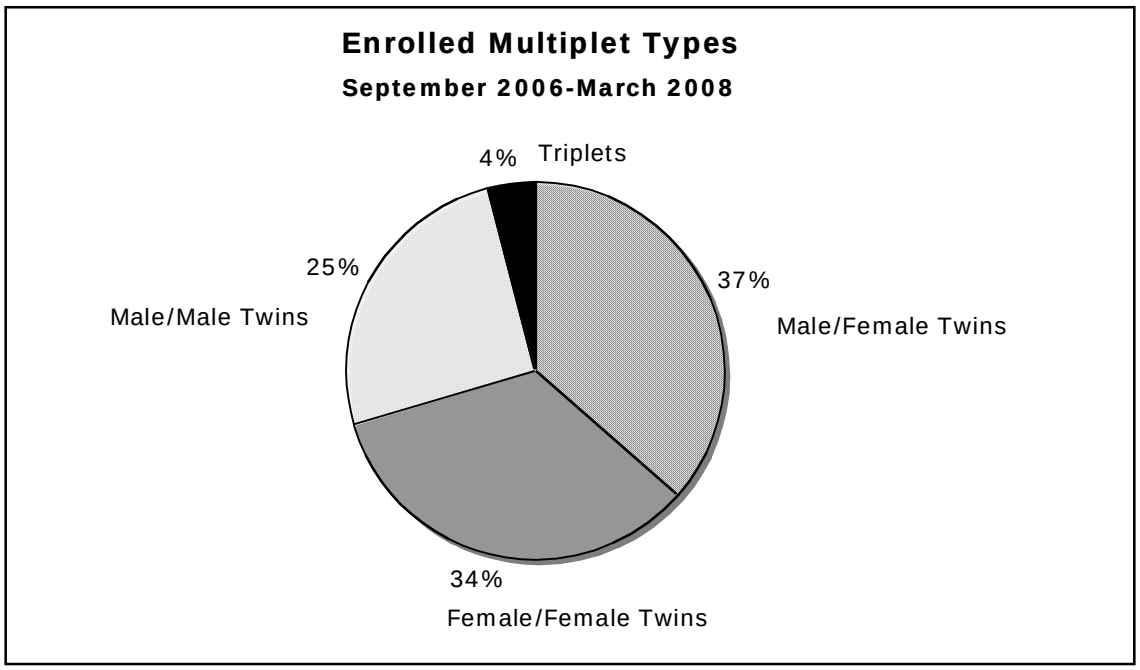

Figure 1. PRIM Enrollment by Multiplet Type

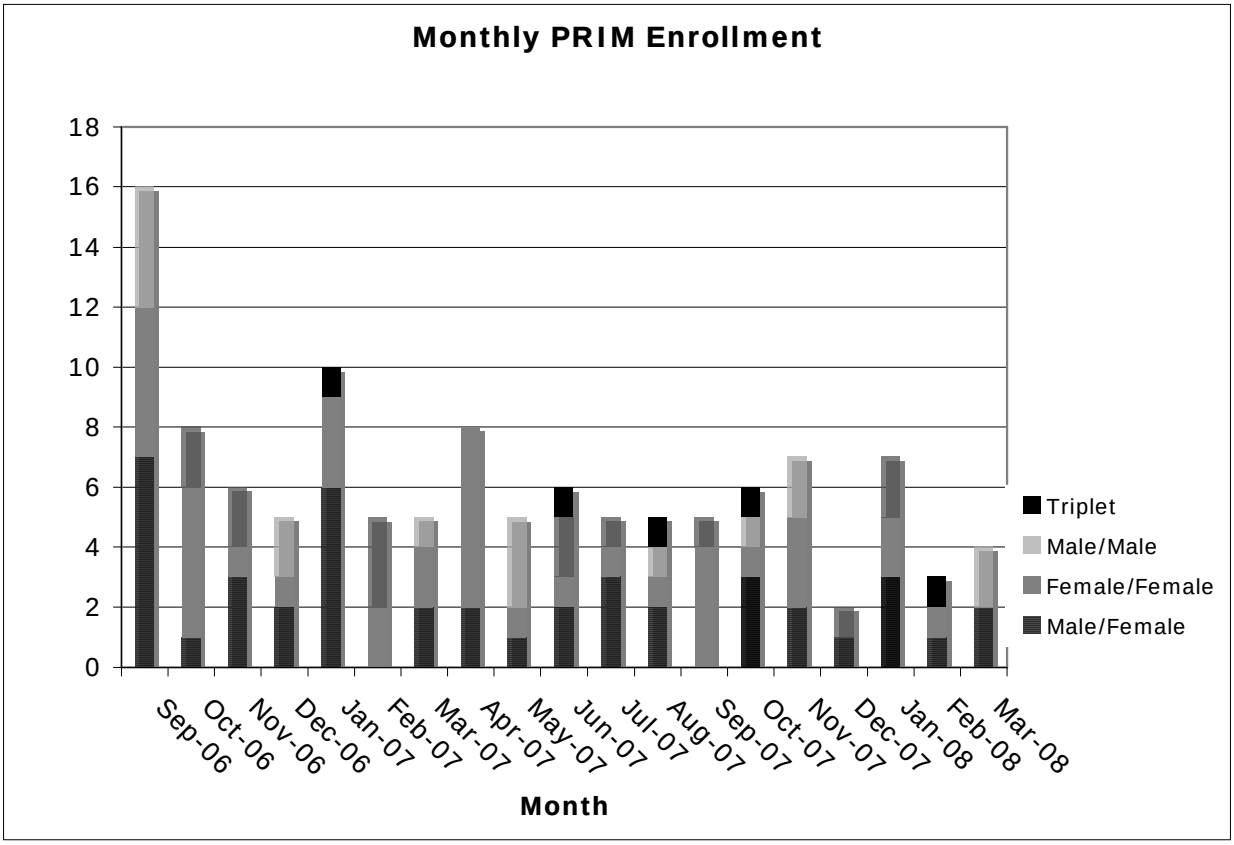

Figure 2. Monthly PRIM Enrollment by Multiplet Type

3.0 BACKGROUND AND SIGNIFICANCE

3.1 THE TWIN METHOD

The use of twins for studying similarities and differences between individuals dates as far back as 400 C.E. (Neale & Maes, 2004). More formal, research-oriented interest in twins dates to the 19th century. Francis Galton, cousin to Charles Darwin, is often credited with being among the first to suggest the use of twins in research of "nature versus nurture." In Galton's 1875 paper entitled "The History of Twins, as a Criterion of the Relative Powers of Nature and Nurture" he sought to explain the inheritance of mental ability by examining similarity between twins. As interest in genetics grew, so did the knowledge of inheritance and trait variation. Rediscovery of Mendel's plant hybridization work established regularities of particulate inheritance. Ronald Fisher (1918) showed how continuous variation could be consistent with discrete inheritance. The polygenic model of inheritance, as a concept introduced by Fisher, explains the phenotypic variation of a trait within a family due to environmental and genetic effects (Neale & Maes, 2004).

Family, twin, and adoption studies provide opportunities to examine the relative contributions of genes and environmental elements to variation in traits in the population. Twins are a particularly important source of data for biometric genetics. The rate of twin and higher order multiple births has risen nearly 70% since 1980. In 2005, approximately 16 of 1000 births

were a twin birth; the rate of higher order multiple births has declined slightly (Hamilton *et al.*, 2007). Two main trends have been proposed to explain the continued increase in the twinning rate, older maternal age and assisted reproductive technology (ART). There is a general trend for women to postpone childbearing until later and women in their 30s at the time of pregnancy are more likely to have twins than younger women. The increased use of ART is a major cause of the increased twinning rate. ART use, and resulting births, has more than doubled since the mid-1990s. Not only are women in their 30s more likely to have twins, but they are also more likely to use ART; over half of ART cycles performed in 2005 were for women over age 35 (Centers for Disease Control, 2007). Though the rate of multiple births as a result of ART has decreased from 2004 to 2005, about 32% of live births resulting from ART are multiples (twins, triplets, or more) (Centers for Disease Control, 2007).

Genetically, there are two types of twins, monozygotic (identical) and dizygotic (fraternal). Monozygotic (MZ) twins are thought to be a sporadic occurrence, happening with some consistency in about 4 per 1000 pregnancies (Martin *et al.*, 1997). MZ twins occur as a result of one zygote splitting soon after fertilization. MZ twins are essentially genetically identical, as they share all (100%) of their genes in common. Dizygotic (DZ) twins result from separate fertilization events of two eggs released at the same time. DZ twins share, on average, half of their segregating genes in common (identical by descent, IBD) and are as genetically related to each other as any other sibling pair. Many factors have been suggested to be related to DZ twinning including age (being over age 35), parity (more children prior to a twin conception), body composition (being taller, having a higher BMI), seasonal (more twin conceptions in summer and fall), race (higher twin rates in African and African American women), and genetics (some families show autosomal dominant patterns of inheritance for twin

births) (Hoekstra *et al.*, 2008). Although DZ twins are no more alike than siblings born at different times, the advantage to using DZ twins in genetic research is that some traits vary developmentally, and in siblings of the same age (DZ twins) this age confounder is removed (Martin *et al.*, 1997).

The main foundations of the twin method are the difference in the genetic relatedness of the MZ and DZ twins and the assumption that the environments for MZ and DZ twins are equal. The equal environments assumption has been found to hold true in studies of some complex traits, including parenting styles. Studies utilizing parent self-reporting found that there were no significant differences in the treatment of MZ and DZ twins by the parents (Cohen *et al.*, 1977; Kendler *et al.*, 1992). Because MZ twins share all of their genes in common, and DZ twins share 50%, the additive genetic correlation between MZ twins is 1 and between DZ twins is 0.5. The extent to which MZ twins differ is attributed to non-shared environmental factors, whereas the differences between DZ twins can be due to both non-shared genetic and non-shared environmental factors. If genetic factors account for the entirety of phenotypic similarity on a given trait, MZ twins will be twice as phenotypically similar as DZ twins.

3.1.1 Biometrical Genetics: Twin Method

Biometrical genetics considers phenotypic variation as composed of two broad parts: the contributions from genetics and environment (Evans *et al.*, 2002; Neale & Maes, 2004). The biometrical approach to studying phenotypic variation relies on the patterns of resemblance within families. Twin studies are a useful design in biometrical genetics analysis because some preliminary information about the major sources of environmental contributions to phenotypic variation can be gleaned (Neale & Maes, 2004).

Assuming panmixia and the absence of gene-environment interactions and epistatic effects, the phenotypic variance of a particular latent trait, V_P, is usually modeled as composed of the additive genetic component, V_A, the dominant genetic component, V_D, and a shared, V_C, and non-shared or unique, V_E, environmental component and represented as:

$$V_P = V_A + V_D + V_C + V_E$$

(Neale & Cardon, 1992). V_A represents the phenotypic variance attributable to the additive effects of alleles across one locus and V_D refers to the non-additive variance due to interaction between two alleles at one locus. The shared environmental variance, V_C, is due to non-genetic factors that tend to make family members more similar to one another and V_E is a measure of the proportion of variance due to factors that contribute to phenotypic differences between family members and include measurement errors (therefore, always present).

A measure of the extent to which genetic effects influence phenotypic variation is heritability. Broad sense heritability (H^2) is a measure of all genetic effects combined ($V_A + V_D = V_G$), $H^2 = V_G / V_P$. Narrow sense heritability (h^2) is the effect of additive genetic factors on phenotypic variation, $h^2 = V_A / V_P$ (Neale & Maes, 2004).

Genetic variation of a trait is primarily composed of the sum of two components: additive and dominance genetic effects. Phenotypic variation from the contribution of additive genetic factors (a^2) can be calculated as two times the difference between MZ and DZ twin correlations, respectively, $a^2 = 2(r_{MZ} - r_{DZ})$. Contribution of dominance genetic factors (d^2) can be calculated as: $d^2 = 2r_{MZ} - 4r_{DZ}$ (e.g. Posthuma *et al.*, 2003). The total genetic variation of a trait involves additive and non-additive effects, the latter including dominance and epistatic effects. Non-shared environmental influences are indicated by MZ correlations of less than 1.0. The contributions of environmental factors are calculated as: e^2 (non-shared factors) = $1 - r_{MZ}$ and c^2

(shared) = $2r_{DZ}$ - r_{MZ} (e.g. Posthuma *et al.*, 2003). These estimates of phenotypic variance depend on the accuracy of the correlations estimated for the MZ and DZ twins of interest. The biometrical genetics approach using path analysis has become a standard method for investigating the effects of genetic and environmental variance components on the overall phenotypic variance of a trait.

Path analysis was first described by Sewell Wright in 1921 (Neale & Maes, 2004). Path diagrams are used as visual representations of the relationships between variables, which allow predictions about variances and covariances to be derived. Path analysis allows the user to make specific hypotheses about the relationships between variables and enables comparison of the models predictions with the observed data. In these diagrams (Figure 3), arrows depict the relationships between latent (circles) and observed (rectangles) variables. A two-headed arrow indicates a covariance/correlation, used to quantify similarities between related individuals or variables. One-headed arrows represent a hypothesized directional ("causal") relationship between two variables, with corresponding path (partial regression) coefficients. In Figure 3, the variable at the tail of the arrow is the latent variable which influences or causes the observed variable/trait at the head of the arrow (Neale & Maes, 2004).

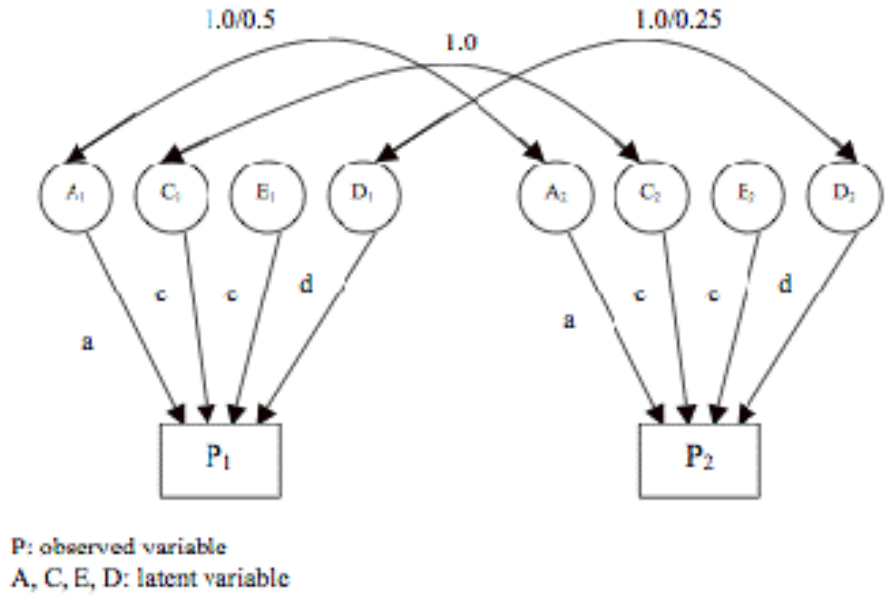

Figure 3. Twin model univariate path diagram

Some assumptions of the method of path analysis include linearity (all relationships between variables are linear), causal closure (all direct influences of one variable on another must be included in the diagram), and unitary variables (variables must not be composed of subcomponents) (Neale & Maes, 2004).

By tracing the paths, the relationships between the twins (labeled as 1 and 2) can be estimated. Wright showed that if a situation can be modeled by an appropriate path diagram, then the correlation between any two variables in the diagram can be expressed as a sum of compound paths connecting these two points. A compound path is a path along arrows that follow three rules: 1) no loops, b) no going forward then backward, and 3) a maximum of one two-way (two-headed) arrow per path. The relationships between the twins can then be calculated by tracing the paths (three paths per twin):

For MZ: $a \times 1 \times a = a^2$ and $c \times 1 \times c = c^2$ and $d \times 1 \times d = d^2$

For DZ: $a \times .5 \times a = 0.5a^2$ and $c \times 1 \times c = c^2$ and $d \times 0.25 \times d = 0.25d^2$

Thus correlations between the MZ and DZ twins are:

$$Cov(MZ) = a^2 + c^2 + d^2$$

$$Cov(DZ) = 0.5a^2 + c^2 + 0.25d^2$$

(Neale & Maes, 2004)

Path analysis is a type of structural equation modeling in which multivariate approaches allow the relationships between variables to be examined simultaneously. The goal of path analysis is to find a model that fits the data in a realistic manner. Model fitting analyses allow for determination of whether the data are consistent with only additive genetic effects (A), whether or not there are significant dominance genetic effects (D) present, and whether an environmental model (C indicates shared environment and E indicates unique/nonshared environment) can be rejected. The nonshared environmental component cannot be dropped from the model, because it includes the unavoidable measurement error. When utilizing the twin study design, D and C cannot be estimated simultaneously (i.e. each are considered in separate models) because they are confounded in the twin data. Since shared environmental effects increase DZ similarity relative to MZ correlations, and dominance effects decrease it, simultaneous modeling of both may result in negative variance component estimates (Neale & Maes, 2004).

Model fitting for variables that are continuously distributed should be done using variance-covariance matrices because differences in variance between MZ and DZ twins may be observed whereas these differences could be overlooked by using correlations (Neale & Maes, 2004). A good fit is indicated by the absence of significant differences between expected and observed data; therefore a large χ^2 value (and low p value) indicates poor fit of data to the

model being investigated. Models with p-values less than 0.05 are rejected. If both and male and female twins pairs are present in a sample, possible sex-dependent effects may be investigated. To do so, analyses may be done separately for each sex and the results compared or a sex-limitation modeling approach can be applied. Path analysis and modeling are performed using software programs such as Mx (Neale & Maes, 2004).

Biometrical genetic analysis and the twin study design are well-suited approaches for this study, which seeks to elucidate sources (genetic and environmental) of phenotypic variation for two complex traits. Perception of parental behavior, as measured by the revised Children's Report of Parental Behavior Inventory (referred to as PB in this study), and the Liability Index, a measure of transmissible liability to substance use disorders are both complex characteristics with continuous distribution of values.

3.2 PERCEPTION OF PARENTAL BEHAVIOR

Parent-child relationships are important in the development of the child's personality and behavior. One aspect of this relationship is the style of parenting behavior. Parenting styles describe the behavior of the parent towards the child and may classified in many different ways. Acceptance and rejection is one dichotomous example of parenting style in which acceptance is characterized by behaviors of warmth, support, nurturing, and affection towards the child and rejection is a style of withdrawal or the absence of love towards the child (Rohner & Britner, 2002; Veneziano, 2004). Research in the area of child development and behavior has reported that parenting styles not only contribute to the child's development, but the child's perceptions and representations of parent behavior and family dynamics also influence emotional and

behavioral development. Behavior genetics research has shown the variation in child's perception of family to have genetic influences (Rowe, 1981; Kendler, 1996; Lichtenstein *et al*, 2003.

Parenting behavior is likely a product of human biology as well as cultural and social cues and expectations (Veneziano, 2004). Mothers are traditionally viewed as the primary and more capable caregiver while the fathers' role has historically been seen as peripheral. Mother-child interactions tend to occur more often than father-child interaction, and each have distinct areas of focus (reviewed by Collins & Russell, 1991). Mother-child interactions are more focused on personal issues and intimate connection whereas fathers spend more time with goal-oriented topics and tasks of mastery and understanding, such as schoolwork or athletics. Parents exhibiting protective, caring, affectionate and helpful behaviors are viewed more positively (Stadelmann *et al.*, 2007). Mothers are typically classified as being more affectionate, more loving, and less neglecting than fathers. According to a review of the literature by Goldin (1969), fathers are generally perceived as being less indulgent and more powerful than mothers. A tenable thought is that these conventional depictions of parent roles, prevalent throughout societies, inform the backdrop against which children develop positive or negative perceptions of their parents. Actual as well as perceived deviations from this norm likely lead to behavior problems and are speculated to occur more often in mother-child relationships than those between father and child (Collins & Russell, 1991).

3.2.1 Effects of Parent Behavior on the Child

Parenting behaviors and their impact on a child's development have long been an interest of researchers. In general, a negative perception of parent behavior or family dynamics has a

negative impact on the child's psychological and behavioral development (Baumrind, 1991, Campo & Rohner, 1992; Pike & Plomin, 1997). The child's perception of this relationship is not related to the parent's perception and in many cases can be quite the opposite. Rask *et al.* (2003) found that the adolescent's perception of family dynamics, of which parent behavior is a part, contributed to his or her overall, subjective well-being. Parents' reports of family dynamics were not associated with either the adolescents' family perception or subjective well-being. The parental acceptance-rejections theory (PARTheory) predicts that rejected children tend to have more behavior problems, such as aggression and low self-esteem, than accepted children (Rohner & Rohner, 1980).

As early as the kindergarten years, representations of the family can predict development of conduct problems. Stadelmann *et al.* (2007) found that the number of negative parent representations in a child's narrative story was positively correlated with symptoms of conduct problems and, to a lesser degree, hyperactivity. More positive representations were associated with pro-social behavior, which describes the behavior of an individual acting to help or provide benefit to another. During adolescence, negative maternal perception has been shown to be associated with depressive symptoms and antisocial behavior (Pike & Plomin, 1997). In his review of children's reports on the behavior of their parents, Goldin (1969) evaluated the impact of three primary domains of parent behavior: Love (acceptance versus rejection), Demanding (autonomy), and Punishment (control). With respect to the Love domain he found that children with behavior problems reported that their parents were rejecting and the family was generally classified as maladjusted. Rejection experienced by a child tends to be associated with the development of depression and behavior problems at some point in childhood, adolescence, or adulthood (Rohner & Britner, 2002). In areas of Demanding and Punishment the parents of

children with behavior problems were described as not setting or enforcing limits, having lax discipline, and lower authority (Goldin, 1969). Ausubel *et al.* (1954) found that girls, more than boys, perceive they are more accepted by their parents.

Substance abuse among adolescents has been shown to have some associations with parent behavior, much the same way behavior problems are associated. Baumrind (1991) studied adolescent substance use, ranging from nonusers (no drug or alcohol use) to heavy and drug-dependent users. For each group, parenting style was evaluated using criteria for six types. *Authoritative* parents were highly demanding and highly responsive; *democratic* families were highly demanding, moderately responsive and not restrictive; *directive* families were demanding, responsive and valued conformity, *good-enough* families showed low to medium levels of demanding, responsiveness and restrictiveness; *nondirective* parents had very low levels of demanding, responsiveness, and restrictiveness in their parenting style; and *unengaged* parents do not structure or monitor their children (Baumrind, 1991). It was found that parents of heavy or drug-dependent users were less directive and exerted less assertive control that those of nonuser teens. A more permissive style (i.e. less demanding) of parenting, compared to an authoritative style, was also associated with heavier drug use (Baumrind, 1991). In a study by Campo and Rohner (1992) of substance abusers, maternal rejection was felt significantly more often by abusers than nonabusers. Additionally in this sample, paternal rejection was also higher in the substance-abusing group (Campo & Rohner, 1992). The effect of parent behavior on a child's substance use is likely to be both direct and indirect. The direct effects of too much freedom and too few rules may contribute to substance experimentation or abuse. Psychological consequences of parent behavior, such as depression resulting from parent rejection, may also contribute to adolescent substance use (Rohner & Britner, 2002).

3.2.2 Measurement of Parent Behavior Perception

To study the environment is to simultaneously study the person, as Jessor and Jessor (1973) explain. They describe two categories of environment that an individual experiences concomitantly: distal and proximal. The distal environment is more remote from direct experience and includes such areas as climate, or geography, which do not have immediate functional significance or psychological implications. It is the proximal environment (e.g. social approval, expectations of others, models of action), which involves the perception of one's environment; it allows the individual to interpret and apply meaning to his or her environment. The perceived environment is complex, involving gradations of proximal and distal experiences, general perceptions and event-specific perceptions, all of which can and do change with an individual's development. This complexity makes measurements of the perceived environment challenging, particularly when considering a subjective approach of study; confusion may arise between environmental variance and person variance (Jessor & Jessor, 1973). Regardless of the possible complexities and confusion, measure of the child's perception of parent behavior is likely the most direct and relevant measure of the impact of the family environment on the behavior development. The child reacts not to the objective environment (e.g. parent behavior), but to his/her interpretation (i.e. perception) of that environment (Ausubel *et al.*, 1954).

To measure the proximal, or perceived, environment, questionnaire or interview based protocols are more common than observational studies, which are typically used to measure interaction with one's environment. In his 1969 review of the literature, Goldin (1969) evaluated over 60 studies of child perception, all of which utilize some method of reporting by the child. Studies employ various methods of eliciting responses from children including questionnaires

(Schaefer, 1965; Roe & Seigelman, 1963), sentence completion or narrative creation (Mussen & Distler, 1959; Stadelmann *et al.,* 2007).

The Children's Report of Parental Behavior Inventory (CRPBI) is one common scale used to evaluate the parent-child relationship. Developed by Schaefer (1965), this scale measures concepts including autonomy, encouragement, protectiveness, control, rejection, and neglect. There is a 10-item scale for each of 26 concepts. Examples of questions from the scales developed by Schaefer (1965) include:

> My mother/father enjoys talking things over with me.
> My mother/father thinks I am not grateful when I don't obey.
> My mother/father smiles at me often.
> My mother/father allows me to go out as often as I please.

For each question, the child can respond using a 3-point, Likert-type scale.

Other researchers have revised this scale in part, because of the length of the original questionnaire, which is sometimes difficult to administer, especially to young children and adolescents. Additionally, the original CRPBI measures scales that are similar to each other and can be difficult to interpret if inconsistent results are returned. Smaller empirical scales can be developed to maximize interpretability of results. Several researchers have developed such revised scales including a 108-item scale from Schludermann and Schludermann (1970), and a 90-item scale developed by Raskin *et al.* (1971). Schludermann and Schludermann (1970) chose to revise the original CRPBI to make it more feasible to administer to young children with short attention spans as well as more culturally appropriate by eliminating particular questions. The 56-item CRPBI is another such scale, developed by Margolies and Weintraub (1977). This shorter version, as with the original, assesses three main domains of parenting: love, autonomy, and control over six different Likert-type scales.

3.2.3 Genetics

Whereas parental behavior can be viewed as an environmental component of a child's life, its measures may have several sources of genetic influence in the variation of both the true trait and the measurement method, including the informant. For instance, direct observation of parental behavior would essentially deal with parental behavioral traits, potentially significantly heritable. Inasmuch as parental behavior towards the child may be reactive to the child's behavior, thereby inducing genotype-environment correlation, it may also include heritable components of the child's behavioral traits. Child's report on parental behavior may additionally contain heritable contributions of the child's own relevant behavioral traits. Alternatively, these heritable contributions may be relatively small, and the child's report on parental behavior may be largely reflective of parenting as an environmental factor. Plomin *et al.* (1994) suggest that any study of differences in the parent-child relationship should include a study of genetic influences. A biometrical genetics approach is an appropriate method to use to study the complex trait of parental perception.

The first major study of children's perception of their parents with a focus on genetics was done by Rowe in 1981. In this study, 89 twin pairs (46 monozygotic [MZ] and 43 dizygotic [DZ]) were compared to evaluate genetic influences on variation in parent perception as measured by the CRPBI developed by Schaefer (1965). This study showed that MZ twins were more similar in their perception of maternal and paternal behaviors than DZ twins, specifically in the area of acceptance-rejection. A subsequent study found, again, that individual differences in perception of parental behavior in the area of acceptance-rejection are partly due to genetic influences (intraclass correlation $r_{MZ} = .63$, $r_{DZ} = .21$), whereas those in the areas of control are not (intraclass correlation $r_{MZ} = .44$, $r_{DZ} = .54$) (Rowe, 1983). Multiple researchers, using a

variety of parent perception measures, have obtained similar results. Pike & Plomin (1997) found heritability for perception of maternal and paternal behavior ranging 0.23 - 0.56, with measures of positivity (e.g. warmth, support, empathy, rapport) showing higher heritability, than measures of negativity (e.g. feelings of anger, frequency and intensity of parent-child disagreements). This heritability estimate was greater for mothers than fathers. Plomin *et al.* (1994) found multiple measures of the family environment to have moderate estimates of heritability, including measures of positivity, a domain including warmth, support, and empathy (h^2 = .49 for mothers and .53 for fathers). Domains of control had lower heritability than did those of positivity. Kendler (1996) obtained heritability estimates of 0.63 and 0.47 for mothers and fathers respectively in the warmth domain, and heritability around .25 for measures of protectiveness and authoritarianism as reported by the children. It has also been found that variation in recalled memories of parental behavior shows genetic influence, and more so in areas of parental warmth than control. Lichtenstein *et al.* (2003) found that about 30% of variation in memories of parental warmth is due to genetic influences. Additionally, studies of observed parent-child interactions show significant genetic components in the relationships between parents and children, though questionnaire-based studies consistently report higher heritability measures (O'Conner *et al.*, 1995; Rende *et al.*, 1992; Neiderhiser *et al.*, 2004).

The results of multiple studies showing that perception of parent behavior, a measure of the environment, has significant heritability shed light on the causal relationship between parents and children. Genotype-environment correlations describe the concept of genetic contribution to variation in environmental measures, reflecting the nonrandom distribution of environments among genotypes (Neale & Maes, 2004). Three types of genotype-environment correlations (r_{GE}) have been proposed. Passive r_{GE} occurs when the genes underlying the heritability of a trait

contribute to variation in parental behavior as an environmental factor; it is a process independent of the individual. Active r_{GE} results from the individual contributing to his/her own environment by seeking out that which is related to his/her genotype for a particular trait. Evocative (reactive) r_{GE} occurs when people react differently to individuals of different genotypes for a given trait; a particular environment is provided to the individual because of the reactions of others (Plomin *et al.* 1977). These correlations may be positive or negative. As discussed by Neiderhiser *et al.* (2004), genetic influences on parenting style may be different depending on the study design used. The difficulty with using only a child-based study design is that the type of r_{GE} cannot be disentangled. A combination of parent and child-based measures are most useful for determining the presence of passive or nonpassive r_{GE} (Neiderhiser *et al.*, 2004).

An additional consideration for the separation of genetic and environmental effects is that of assortative mating, or nonrandom pairing of mates. In human populations, assortative mating occurs for a variety of traits such as education, religion, attitudes, and personality. Assortative mating tends to be positive, meaning that mates are chosen based on similarity to oneself. Assortative mating may be influenced by genetic and environmental effects and in turn may affect the correlation of genetic and environmental effects in subsequent generations. The presence of assortative mating in a population is seen as a correlation between mates for a given trait (homogamy). Positive assortative mating induces genetic and environmental correlations between unrelated mates and increases the genetic correlation between relatives. Therefore, it can increase the similarity of DZ twins relative to MZ twins and estimates of the genetic component for a given trait will be biased downwards (Neale & Maes, 2004).

There have been a number of studies evaluating the effects of parenting, as described above in this section. The majority of these studies have investigated effects of parenting in mothers alone or mothers and fathers combined as a parenting unit. There are fewer studies considering the parenting behavior mothers and fathers separately. The effects on the child of parenting behavior have been focused on behavior problems and substance use disorders. More recently, genetic analyses have been employed to study the relative effects of genetic and environmental influences on variation in parental behavior as well as the child's perception of that behavior. This study seeks to further evaluate possible differences in maternal and paternal parenting relationships as perceived by their children. Whereas other studies have looked at specific domains of parent behavior (e.g. love, acceptance, rejection), this study uses a measure of a broad, or more global, perception of parental behavior to evaluate differences in maternal and paternal parenting styles. A goal of this study is to add to the body of research on the heritability and effects of parental behavior perception by examining correlations between this perception and the risk to develop substance use disorders in children as well as considering any gender differences in the sample.

3.3 LIABILITY TO SUBSTANCE USE DISORDERS

Substance use disorders (SUD) are a large public health concern, particularly in the context of prevention. Data from the National Institute on Drug Abuse (NIDA) (2003) estimate that in 1998 approximately 86 million individuals over age 12 have used, at some point in their life, an illicit drug. Approximately 14 million individuals had used within the preceding month. Broken down by age, estimates are that nearly 10% of 12-17 year olds had used an illicit drug in the

preceding month (NIDA, 2003). A single use does not define a substance use disorder. According to the Diagnostic and Statistic Manuel (DSM-IV) substance-related disorders can be quite diverse in their phenotype, being classified as either substance abuse or substance dependence disorders. Each classification requires that a certain number of criteria be met to establish the diagnosis; one or more of 4 criteria for substance abuse (such as recurrent use despite physical harm, social harm, legal problems), and three or more of seven criteria for substance dependence (American Psychiatric Association, 2000). This clinical heterogeneity can make teasing out genetic and environmental influences a challenge, as well as making the determination of a liability threshold, above which the phenotypic trait is observed, difficult to establish.

Researchers have examined the heritability and transmissibility of liability to substance disorders as a phenotypic trait and found various levels of genetic contribution to its variance. As mentioned above, the clinical definition of substance use disorders is heterogeneous, and many studies find that the genetic and environmental influences are dependent on the severity of the disorder (e.g., abuse versus dependence) and, much less, type of substances used (e.g., licit vs. illicit). One study found that for drug abuse and/or dependence, for any drug, the additive genetic influence was as high as 0.79 for males and 0.47 for females. In particular, for drug dependence, genetic influences are more contributory, whereas for drug abuse, shared environmental factors contribute to a greater degree (van den Bree *et al.*, 1998). Walden *et al.* (2004) using a twin design research study found that common environmental factors accounted for the majority ($c^2 = 0.51$) of phenotypic variance for early substance use. Young *et al.* (2006) found modest genetic contributions to substance use ($h^2 = 0.29\text{-}0.49$) and noted that the environmental contribution was specific to the substance being used.

It has been suggested that there is some underlying factor to the development of SUD, specifically, an externalizing factor related to under control of behavior or behavior disregulation. These factors have been found to be stable over time (as the child develops) and seem to have some continuity among those who later develop SUD (Zucker, 2006). A lack of inhibitory control or behavior disorders such as attention deficit and hyperactivity disorder (ADHD) or conduct disorder (CD) seems to be associated pathways leading to risk for SUD (Pears *et al.*, 2007; Young *et al.*, 2000). These underlying pathways and influences may all be part of a general, or common, liability to SUD.

The liability to a complex disease, such as SUD, comprises both the individual's innate tendency to develop the disease (i.e. susceptibility) and the combination of external factors that contribute to the likelihood of disease development (Falconer, 1965). In other words, the liability is the result of all factors that contribute to the variation in the risk to develop a disorder; it can be referred to as a polygenic or multifactorial trait. The liability is an unobservable (latent) trait with an assumed normal distribution along a scale of standard deviation (Figure 3). At some point along the scale, a threshold is met. Individuals whose liability is below this threshold do not have the disease of interest, however those with a liability above the threshold will express the phenotype of the disorder (Falconer, 1965).

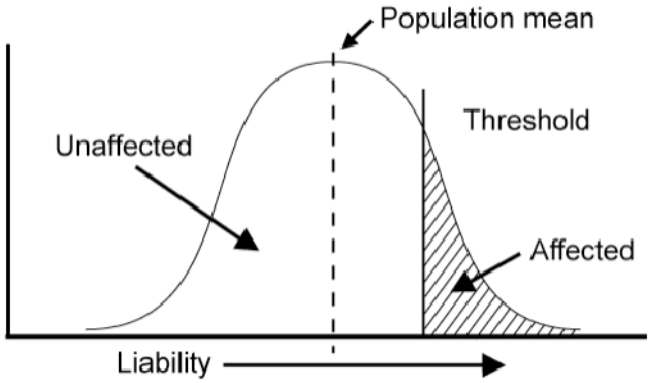

Figure 4. Threshold Model for Complex Traits

The liability trait is influenced by genetic (additive and dominance variance) and environmental factors (shared and nonshared) and it may be possible to estimate the magnitude of these influences at the individual level. For a trait such as liability to substance use or other behavior disorders, these effects may be best studied using a twin or adoption study approach to examine the contributions of genetic and environmental factors (Vanyukov & Tarter, 2000). Evidence for common underlying liability to the complex disorder of SUD was discussed above. Studies have shown that variation in liability to SUD is strongly influenced by genetic factors (Young *et al.*, 2006; Pears, 2007; van den Bree *et al.* 1998). Importantly, these factors are not specific to substances, but virtually entirely shared in common for disorders related to illicit drugs (Tsuang *et al.*, 1998; Kendler *et al.*, 2003) and to licit substances, with the two genetic factors highly (r=0.8) correlated (Kendler *et al.*, 2007). This indicates the validity and utility of the common liability notion beyond its meaning as a statistical abstraction. Measurement of this latent trait can be used to determine how close to the threshold of phenotypic SUD an individual may be, prior to an age when substance use typically begins. This early identification of at-risk individuals may lead to strategies for prevention. With these objectives in mind, an index of

transmissible liability to SUD (liability index, LI) has been created (Vanyukov *et al.*, 2003a,b). To derive the LI, the study population was chosen based on the high-risk paradigm; children from high-average risk (HAR) and low-average risk (LAR) families were selected (risk was determined by the SUD affected/nonaffected status of the father). The procedure is described in detail below in the Methods section.

A large portion of variance in liability is accounted for by genetic factors shared in common between attention deficit hyperactivity, conduct and oppositional defiant disorders (ADHD, CD and ODD) (Silberg *et al.*, 1996; Nadder *et al.*, 1998; Young *et al.*, 2000) which are also well-known precursors to SUD (e.g., Zucker, 2006). Burt *et al.* (2001) found, however, that the same environmental factor(s) determine non-genetic similarity between twins for the risk for ADHD, CD, and ODD. Parent-child conflict has been shown to be among these environmental factors, accounting for a significant proportion of the shared variance (Burt *et al.*, 2003). This study, employing twin design, addresses sources of variation in parenting and in the latent trait of the liability to SUD as measured by the LI, and their relationship.

4.0 METHODS

4.1 SAMPLE POPULATION

Participants for this research study were recruited at the Twins Days Festival in Twinsburg, Ohio during 2006 and 2007. This festival is an annual summer occurrence for twins and higher order multiples of all ages and their families from around the country. The festival is an opportunity for families to play games, participate in twin competitions (e.g. most alike fraternal twins, most dissimilar identical twins), and interact with other families in a carnival-like atmosphere. It is also a unique opportunity for research participation as researchers from around the country set up space to conduct their research study. Participants in this study were invited if they had registered with the Twins Day Festival, were between 9-18 years of age, and had at least one parent available to participate as well. Parents were required to consent to the study and the children's assent was obtained. Each family member independently completed anonymous paper-and-pencil questionnaires, which took, on average, 30-40 minutes to complete. Additionally, family members were asked to provide saliva samples in a DNA collection container.

This study was conducted with approval from the University of Pittsburgh Institutional Review Board (IRB #060138). The objectives of the overall research protocol were to examine the heritability of behavioral regulation using a variety of behavioral measures. Additionally,

DNA samples were collected for future candidate gene and behavior regulation association analysis.

4.2 ZYGOSITY DETERMINATION

Parents of same-sex twins completed a questionnaire, "About Your Twins" (Appendix A) to determine zygosity. This brief questionnaire was developed by Nichols and Bilbro (1966) and the corresponding zygosity determination algorithm developed by Eley and the collaborators for the Twins Early Development Study (TEDS) in London (personal communication [Strassberg *et al.*, 2002; Jenkins *et al.*, 2006]). The questionnaire is composed of 15 items to determine the similarity and differences between members of the twin pair. It has an accuracy of 94% for zygosity determination when compared with blood test results (e.g. Rowe, 1981; Strassberg *et al.*, 2002).

4.3 CHILDREN'S REPORT ON PARENTAL BEHAVIOR INVENTORY

The Children's Report on Parental Behavior Inventory (CRPBI) was initially developed by Schaefer (1965) to evaluate parental behavior in areas of acceptance, control, and autonomy. The original index was comprised of 26 different concepts, each with 10 questions for the child to answer about each parent. A revised inventory (hereafter, PB), based on the measure described by Schludermann & Schludermann (1970) was used in this study, which was composed of 20 questions, each asked of the mother and father, requiring 40 total responses from

the child (Appendix B). The concepts measured by this revised scale include domains of closeness and control. The PB is a Likert-type scale with three response choices, "not at all true", "somewhat true", or "very true".

Responses to the PB were recoded to be unidirectional. The positively worded questions (numbers 1, 2, 4, 7, 9, 11, 13, 14, 15, 19) were assigned scores of zero (0) for "not at all true", one (1) for "somewhat true", and two (2) for "very true". The reverse was true for negative questions (numbers 3, 5, 6, 8, 10, 12, 16, 17, 18, 20) where zero (0) corresponded to "very true", one (1) for "somewhat true", and two (2) for "not at all true". Missing responses were replaced using mean substitution. For this study, an index score was derived for each parent by summing the response scores. A low index value corresponds to a lower, or more negative, perception of parental behavior.

4.4 SUD TRANSMISSIBLE LIABILITY INDEX

The Liability Index (LI) used in this study (Vanyukov & Tarter, 2000; Vanyukov *et al.*, 2003a,b) was developed in response to a lack of quantitative measures of SUD risk. As described above, the liability to substance use disorders is a complex latent trait. There are no observable face-value indicators of this trait except for the symptoms of the disorder, which are unavailable in children and in the majority of the adult population. The identification of indicators of this trait in children for the development of the LI was based upon its transmissibility. Children of SUD-affected and –nonaffected fathers differ, on average, in their SUD risk, forming, respectively high average and low average risk (HAR and LAR) groups. Therefore, any HAR-LAR differences in observable psychological characteristics are related to the differences in the

parental SUD liability and, inasmuch as it is transmissible (largely due to its considerable heritability), to the differences in the children's own SUD liability. This has enabled selection of a set of childhood psychological indicators of adult SUD liability from a large pool of items (over 300) comprising standard psychological scales and psychiatric instruments. These items were submitted to conceptual (identification of item groups judged to indicate core psychological traits), factor and item response theory (IRT) analysis to derive theoretically based unidimensional constructs. Item response theory (IRT) is a psychometric test theory relating a latent trait, termed ability, to an individual's performance on test items, taking into account properties of both the individuals and the items. This method is uniquely useful for liability measurement, because it allows integration of disparate information commensurate with the complexity of the trait. The data-fitting IRT models provide trait estimates invariant of the subsets of items used and item parameters invariant of the sample used. The SUD+ and SUD- children groups are then compared on the constructs obtained from the IRT analysis. This comparison relates the constructs to parental SUD liability and, inasmuch as liability is transmissible, to the child's own SUD liability. The constructs demonstrating significant differences are retained, and the items that are indicators of these constructs are submitted to factor analysis to both ensure the presence of a single dominant dimension (unidimensionality) and further reduce the item set. The items comprising the resulting set undergo item response theory analysis to derive an IRT-based final index. The 45-item set thus selected (Appendix C) was used to estimate LI in this study.

4.5 STATISTICAL ANALYSES

4.5.1 Standard Statistics

Descriptive statistics, including distribution, means, and standard deviations were obtained for the PB of each participant using SPSS 16.0 for Mac. Differences in means between independent groups were assessed by t-test (or paired t-test). All reported p-values are 2-tailed.

4.5.2 Reliability Assessment

To evaluate the psychometric properties of the PB-derived scale, a reliability analysis was conducted. The reliability assessment is based on the inter-item correlations for a given measure. The most common index of reliability is Cronbach's alpha. This analysis can be used to assess a variety of items and accounts for how many items are present in a particular scale. Cronbach's alpha is equivalent to:

$$\alpha = \frac{N \times \bar{c}}{\bar{v} + (N-1) \times \bar{c}}$$

where N represents the number of items, $\bar{c}$ is the average inter-item correlation and $\bar{v}$ is the average variance. When alpha is greater than 0.7, a scale is considered reliable (Cronbach, 1951). Reliability analysis was conducted for the PB scale separately for mothers and fathers over the entire sample (N = 612). Cronbach's alpha for mothers' PB was 0.829 (range 0.814 – 0.830) and for fathers' CRPBI was 0.853 (range 0.839 - 0.857). The alpha value showed no improvement with item deletion. Therefore, all 20 items were used.

4.5.3 Correlation and Regression Analyses

Linear regression analysis was used to assess the association between age and PB for mothers and fathers as well as for the LI. Relationships between PB and LI and between fathers' and mothers' parenting measures were determined by correlation analysis, separately for each parent and sex of child. Comparisons of correlations were conducted using Fisher's z test.

4.5.4 Structural Equation Modeling

The goal in building a path diagram or other structural equation model is to find a model that fits the data well enough to serve as a useful representation of reality and a close-fitting explanation of the data. The maximum-likelihood model fitting, applied to variance-covariance matrices on the assumption of bivariate (multivariate) normality maximizes the fit between the model and the data, and then determines those parameter estimates providing the smallest discrepancies with the data. Model fitting offers the advantage of not only testing the fit of a particular model and estimating its parameter, but also allowing a comparison in fit of alternative models.

MZ/DZ correlations can be used to determine which general model – ACE or ADE – to fit to the data first, because, as discussed above, non-additive effects and common environment effects cannot be estimated together in twin data. Nested models, omitting (dropping) one or more of these parameters, are then fitted and the fit indices of all models compared to find the best fitting model.

The chi-square statistic (χ^2) is used as a goodness-of-fit index, evaluating the degree of fit between model expectations and observed data. When assessing the various models, the absence of significant differences between expected and observed data is desired for good model

fit; therefore a large χ^2 value (and low p value) indicates poor fit of data to the model being investigated. Models with p-values less than 0.05 are rejected. Changes in the model's fit from adding or omitting parameters can be assessed by noting the change in chi-square as the difference between the chi-square of an initial model and a nested model, which is itself a χ^2 (Neale & Maes, 2004). Comparisons of the goodness of fit for models using the same number of parameters can also be obtained from Akaike's Information Criterion (AIC). This criterion is one of a class of indices that can provide information about both the goodness of fit of a model and its parsimony or account for observed data with few parameters (e.g. Neale & Maes, 2004). Choosing a model with the least information loss (e.g. the smallest discrepancy between the true and approximating models) is equivalent to choosing a model with the lowest AIC. The AIC is defined as

$$AIC_i = -2\log L_i + 2V_i$$

where L_i is the maximum likelihood for the candidate model and V_i are the free parameters (e.g. Wagenmakers & Farrell, 2004). The number of degrees of freedom used when assessing improvements in the model's fit is equal to the difference in degrees of freedom in the initial model and the nested model.

Univariate model fitting yields estimates of sources of variation in one trait, whereas bivariate structural equation models can estimate the causes of covariation between two traits. Univariate analysis was used to look at the PB and LI, independently. Bivariate analysis can be performed to evaluate the causes of covariation of LI and PB. Genetic and environmental correlations between the traits can be estimated, provided both variables have non-zero heritability and/or environmental components of variance. Model-fitting analyses in this study

were conducted using the Mx structural equation modeling program (Neale *et al.*, 2003). Variance-covariance matrices were used to test the models.

5.0 RESULTS

5.1 SAMPLE STATISTICS

A sample of 306 twin pairs participated in the 2006 and 2007 Twinsburg festival assessments, combined. Ages ranged 9 – 19, with a mean of 13.66 years (SD = 2.49). Out of the total 612 individuals, 365 were female, 245 were male and one twin pair did not report their gender. There were no significant differences in age between sexes (females: N = 365, mean = 13.75 years, SD = 2.46; male: N = 245, mean = 13.53, SD = 2.45; P = 0.283).

Zygosity questionnaires were completed by the parents of same-sex twins. In all, 260 questionnaires were completed. Study participant twin and gender composition can be seen in Table 1.

Table 1. Zygosity and Sex Cross-tabulation of Twin Pairs

	Female	Male	Female/Male	Total
MZ	119	84		203
DZ	39	18	25	82
Total	158	102	25	285

5.2 PB AND LI

The measure of parental behavior perception (PB) was assessed by a revised version of the CRPBI scale (Schaefer, 1965; Schludermann & Schludermann, 1970). Raw PB scores are shown below (Table 2). Age regression analysis was conducted and significant correlations were found for the child's age among PB for fathers, but not for mothers (paternal $r = 0.11$, $p = 0.003$; maternal $r = 0.54$, $p = 0.093$). As such, all analyses of the PB and LI use the data in its original form.

Table 2. PB Raw Score Descriptive Statistics

Child	N	Parent	Mean	SD	Range
Male	245	Mother	9.47	5.66	0 - 30
		Father	9.69	6.44	0 - 31
Female	365	Mother	9.29	6.13	0 - 32
		Father	10.21	6.76	0 - 36

The PB mean for mother and father scores did not significantly differ between Twin A and Twin B (mother: $t = -0.122$, $p = 0.903$; father: $t = -0.333$, $p = 0.739$). As such, correlations for associations between PB and LI were calculated for one member of each twin pair, chosen at random using SPSS random number generator. Mean PB scores also did not differ between sexes of the children (mother: $t = -0.364$, $p = 0.716$; father: $t = 0.969$, $p = 0.333$).

The LI (Table 3) did show significant differences between sexes of the child, $t = -3.846$, $p = 0.00008$. As expected, males' values were higher than females'.

Table 3. LI Raw Score Descriptive Statistics

Child	N	Mean	SD	Range
Male	194	0.22056	1.074	-2.391 – 3.196
Female	308	-0.1389	0.9273	-2.273 – 2.677

Significant relationships were found between the PB and LI, specifically that a higher index score for parent perception was associated with an increased LI. This was true for male and female perception of mothers and fathers (Table 4). The association between maternal and paternal PB and LI did not differ significantly in sons and daughters as well as between sons and daughters, as evaluated by Fisher's z-test (Table 5).

Table 4. Correlations Between PB and LI
(one member of twin pair; zygosity not considered)

Child	N	Parent	Correlation	Significance
Male	97	Mother	.363	.00026
		Father	.325	.001
Female	154	Mother	.353	.000007
		Father	.403	< .000001

Table 5. Comparison of Correlation Coefficients

Groups	z value	P
Son: Mother versus Father	0.2606	0.79
Daughter: Mother versus Father	0.4344	0.67
Mother: Son versus Daughter	0.0761	0.94
Father: Son versus Daughter	0.594	0.56

Data were analyzed to compare measures between MZ and DZ twins and results can be seen in Table 6. All correlations for MZ twins are statistically significant. Correlations for DZ

twin LI and PB measures did not show statistical significance at the 0.01 level. Correlations between the PB of mothers and fathers were significant within and between twin pairs of both zygosities.

Table 6. Overall PB and LI Correlations by Zygosity
(cells also list significances and sample sizes)

DZ / MZ	LI – Twin 1	LI – Twin 2	Mother PB – Twin 1	Mother PB – Twin 2	Father PB – Twin 1	Father PB – Twin 2
LI – Twin 1		0.402 0.004 49	0.418 0.003 49	0.088 0.550 49	0.308 0.031 49	0.243 0.092 49
LI – Twin 2	0.739 0.000 183		0.277 0.054 49	0.297 0.038 49	0.257 0.074 49	0.325 0.023 49
Mother PB – Twin 1	0.352 0.000 183	0.260 0.000 183		0.516 0.000 49	0.727 0.000 49	0.367 0.008 49
Mother PB – Twin 2	0.261 0.000 183	0.388 0.000 183	0.563 0.000 183		0.355 0.012 49	0.703 0.000 49
Father PB – Twin 1	0.368 0.000 183	0.305 0.000 183	0.541 0.000 183	0.249 0.001 183		0.472 0.000 49
Father PB – Twin 2	0.358 0.000 183	0.399 0.000 183	0.320 0.000 183	0.534 0.000 183	0.606 0.000 183	

Intrapair averages were calculated for PB and LI. No significant differences were found between males and females and PB for either mother or fathers ($t = 0.067$, $p = 0.947$; $t = 0.117$, $p = 0.607$). LI was significantly different between sexes ($t = 2.997$, $p = 0.003$). LI and PB correlations using intrapair averages are presented in Table 7. Correlations were not significant in DZ twins when separated by sex.

Table 7. Intrapair Average LI and PB Correlations

		Mother		Father	
Child	N	Correlation	Significance	Correlation	Significance
All	251	0.383	< 0.000001	0.427	< 0.000001
Male	97	0.399	0.000067	0.480	< 0.000001
Female	154	0.391	0.000001	0.429	< 0.000001
MZ	183	0.412	< 0.000001	0.460	< 0.000001
Male	73	0.407	0.000356	0.489	0.000011
Female	110	0.413	0.000007	0.464	< 0.000001
DZ	49	0.366	0.010	0.392	0.005
Male	16	0.439	0.089	0.269	0.314
Female	33	0.397	0.22	0.505	0.003

The perceptions of maternal and paternal behaviors were analyzed for association between parents. This relationship is significantly correlated in both sons and daughters (Table 8). The similarity in mothers' and fathers' parenting style as assessed by child perception tends (nonsignificantly) to be greater in sons ($z = 1.43$, $p = 0.15$).

Table 8. Mother and Father PB Correlations in Sons and Daughters

		One Member of Twin Pair		Intrapair Average	
Child	N	r	P	r	P
Overall	251	0.541	<0.001	0.518	<0.001
Daughters	154	0.499	< 0.001	0.505	<0.001
Sons	97	0.623	< 0.001	0.548	<0.001

5.3 STRUCTURAL EQUATION MODELING

The standard ADE model was fitted to the LI data, and the ACE model fit to PB measures for mothers and fathers separately. Since $2r_{DZ} > r_{MZ}$ for the PB measure (maternal PB: $r_{DZ} = 0.516$, $r_{MZ} = 0.563$; paternal PB: $r_{DZ} = 0.472$, $r_{MZ} = 0.606$), it is unlikely that non-additive genetic effects (D) would have a significant effect on the data, therefore the ACE model was used for this measure. For the LI, the standard ADE model was fitted to the data first because r_{MZ} (0.739) is close to $2r_{DZ}$ (0.402). Model-fitting results are shown in Table 9.

Table 9. Univariate Model Fitting

Model	N Par	χ^2	df	P	AIC	$\Delta\chi^2$	Δdf	ΔP	ΔAIC
LI									
ADE	3	4.225	3	0.238	-1.775				
AE	2	4.225	4	0.376	-3.775	0.000	1		-2.000
E	1	198.077	5	0.000	188.077	193.851	2	0.000	189.851
PB Mother									
ACE	3	9.154	3	0.027	3.154				
CE	2	9.154	4	0.057	1.154	0.000	1		-2.000
E	1	94.876	5	0.000	84.876	85.722	2	0.000	81.722
PB Father									
ACE	3	1.206	3	0.752	-4.794				
CE	2	1.206	4	0.877	-6.794	0.000	1		-2.000
E	1	110.75	5	0.000	100.750	107.356	2	0.000	103.356

For the LI, the AE model fit best, providing a more parsimonious solution and narrow confidence intervals for the model parameters. As shown in Table 10, the LI demonstrated a high heritability of $h^2 = 79\%$, with the rest of the variance accounted for by nonshared environment. The absence of the shared environmental component indicates that only genetic causes underlie intra-pair twin similarity.

Table 10. Univariate Modeling Results: Best Fitting Model

	Variance Component		Fit Index			
Trait	a^2 (95% CI)	e^2 (95% CI)	χ^2	df	P	AIC
LI	0.7919 (0.7348 - 0.8371)	0.2081 (0.1629 - 0.2652)	4.225	4	0.376	-3.775
	c^2 (95% CI)	e^2 (95% CI)	χ^2	df	P	AIC
PB						
Mother	0.5291 (0.1605 - 0.6110)	0.4546 (0.3690 - 0.5519)	3.589	4	0.464	-2.00
Father	0.4506 (0.3486 - 0.5420)	0.5494 (0.4580 - 0.6514)	1.206	4	0.877	-2.00

For the PB measures of both mothers and fathers, the best fitting model was the CE (Table 10). Contribution estimates for shared and unique environmental effects were similar for mothers and fathers, each accounting for approximately half of the variance in PB (Table 10).

5.4 THE RELATIONSHIP BETWEEN PARENTING AND LIABILITY INDEX

Correlation analysis indicates that both paternal and maternal PB assessments are associated with the child's SUD liability. There are no significant differences between the correlations by the sex of the child or the parent (Table 5). Analyzed in MZ and DZ twins, there are also no cross-trait cross-twin correlation differences, suggesting the absence of a genetic correlation between these variables. This is consistent with the absence of a genetic contribution to the PB variance.

As the common environmental component is absent in the LI variance, it stands to reason that the significant intra-individual correlation between the two traits is due to sharing a unique environmental component of the phenotypic variance. The attempts to test, using Mx, bivariate structural equation models, both full ADE and ACE for LI and PB, respectively, and limited to AE and CE as follows from the results of univariate biometric analyses, specifying the E-E correlation, did not result in acceptable fit ($P < 0.001$).

Based upon these results, it appears unlikely that the relationship between the LI and the PB variables in its entirety originates from a common source of variance. It is also unlikely that the directional relationship, if any, could be from LI to PB, as that would introduce a heritable component to the PB variance. It is possible, however, that the PB variables do reflect environmental (parenting) influence, thus being upstream to SUD liability reflected in the LI. Because substantial correlation is observed between the paternal and maternal PB values, to avoid collinearity problem, a path model was fit to the LI and maternal and paternal PB data, averaged within pairs, to determine the contribution of parenting to the LI. As presented in Table 11, both parenting indices, while significantly correlated ($r=0.560$, $P < 0.001$), contribute to the LI. Contrary to expectations, paternal parenting is perceived as no less, and possibly more, influential than maternal.

Table 11. Path Model Correlations Between LI and PB for Mothers and Fathers (β - standardized path coefficient)

Predictor	N	β	P
Average Maternal PB	251	0.220	< 0.001
Average Paternal PB	251	0.329	< 0.001

6.0 DISCUSSION

The delineation of genetic and environmental factors contributing to the liability for substance use disorders has important public health implications. Efforts to describe these contributing factors may lead to opportunities for targeted interventions individuals at-risk for SUD. As these interventions are by their nature environmental influences, it is likely that the results of SUD etiology research would be more readily translatable into practice if they pertained to environmental factors. Genetic studies enable detection of such factors while taking into account genetic variation.

A potential source of a genetically informative sample is a twin registry. One aim of this research has been to continue development of a twin registry for use in biometrical genetic research. The Pittsburgh Registry of Infant Multiplets (PRIM) has continued to grow since its inception in 1996 to over 730 twins and higher order multiples. Recruitment efforts at this time are focused on one hospital in Pittsburgh. The nursing staff is helpful and willing to speak with mothers about allowing the PRIM coordinator to talk with the family. Parents are generally very receptive to the invitation to learn about PRIM. The majority of families choose to participate at this time. There are no clear patterns to describe the declining families. Many indicate they feel they will be too busy to participate. Another large sample of the non-participants indicate at the time of invitation that they would like to think about joining; consent forms are mailed to them with return envelopes, but rarely returned. The most common reason for missing a family is

when the babies are located in the NICU. Parents spend most of their time with the babies and are not in the post-partum suite when the coordinator stops by. Research to date utilizing PRIM has contributed to training and research in behavioral genetics. In general, registries are an important resource to research as they provide a pool of participants from which to select a study population. Sustained growth and development of PRIM will allow for researchers to select from a large sample of twin pairs over a broad age range. Continued maintenance and updating of participant information will make conducting longitudinal studies through PRIM more feasible and effective.

Whereas the sources of genetic variation are well defined by genetic polymorphisms, environmental factors are much more difficult to identify. In addition to their effects' being processed through the prism of personal perception, they are also potentially subject to genotype-environment correlations and interaction. The former are particularly germane to this project, because, along with possible influence of the individual's phenotype on the perception of the environment, these correlations may induce heritable components in environmental influences and, hence, in measures of the environment. The evaluation of variance composition for putative environmental measures, needed for the determination of whether a particular measure is a characteristic of the environment, can be conducted using biometrical genetic approach in a genetically informative sample.

The goal of this study was to examine one such possible environmental factor, the parent-child relationship, specifically in the context of the child's perception of parental behavior (PB). The main objectives were to evaluate the environmental and genetic contributions to individual variation in parent perception and its possible association with the liability index (LI), a measure of transmissible risk to SUD. The PB was chosen because it is a direct measure of one aspect of

the child's environment as perceived by the child. This study used the revised CRPBI as described by Schludermann and Schludermann (1970), and abbreviated the measure to 20 questions to comply with the time limitations of the brief Twinsburg assessment. The PB index was designed to estimate an overall perception of parental behavior by the child, unlike other studies, which have evaluated particular domains of parenting behavior (e.g. love, acceptance, rejection, control) separately (Baumrind, 1991; Campo & Rohner, 1992; Lichtenstein *et al.*, 2003; Rowe, 1981; Schaefer, 1965). As the study results show, the resulting scale has excellent reliability.

These data are consistent with the hypothesis that both maternal and paternal parenting is associated with risk for SUD. These results do not parallel the findings of other studies that negative perception of parental behavior (e.g. rejection, lax control) is associated with problems in behavioral development in the child, which is assessed by the LI in this study (Baumrind, 1991; Campo & Rohner, 1992; Gerra *et al.*, 2007). This positive correlation was an unexpected and counter-intuitive finding and warrants discussion. One explanation may involve methodological differences between this and previous studies. A difference between the PB used in the present study and the literature cited is the global nature of the scale, rather than individual behavior domains. It is possible that PB taps into different behavior domains and effects on the children than those observed in other research.

Another possible explanation may involve characteristics of the study population and selection bias. The studies that have found associations between actual parent behavior or the perception of that behavior with substance use have been composed of drug use and non-use groups (Baumrind, 1991; Campo & Rohner, 1992; Gerra *et al.*, 2007; Vanyukov *et al.*, 2007). Children of drug-using parents are more likely to experience neglect, a factor associated with

behavior problems and substance use in the child (Kirisci *et al.*, 2001; Rohner & Rohner, 1980). The present study was composed of self-selected parents who were attending a family-friendly festival geared towards their children. This may suggest that these parents have more positive relationships with their children when compared to the substance using parents in the cited literature. As LI is derived as an index of transmissible SUD liability, it is possible that PB reflects environmental mediator(s) of the transmissible SUD risk and/or features of parent-child interaction that are secondary to the transmissible SUD risk measured by LI. This, however, would be likely to induce a genetic component in the PB variation, secondary to LI heritability, and thus is unlikely. In this study, the participant sample may have a higher background rate of positive parental perception than the general population.

This study did not find that maternal and paternal parenting differentially affected LI for girls or boys. A previous study using a different index of parenting that included PB items had found that perception of mothers and fathers was differentially associated with behavior disorders as well as depended on the child genotype for the MAOA gene (Vanyukov *et al.*, 2007). At the same time, the latter study provides a precedent for the direction of association that was observed in this project. In particular, *positively* perceived paternal behavior was associated in the child with growth in the risk for conduct disorder – a strong predictor and a frequent developmental precursor of SUD. A lower perceived emotional distance of the father may reflect an overly permissive paternal parenting style, which tends to be associated problem behavior (Steinberg *et al.*, 1994). One possible cause for this influence was thought to be societal expectations for parent behavior. Because fathers are "expected" to be more punitive and less affectionate, a child's perception of this type of behavior does not deviate from the social norm and is less likely to contribute to behavior disorder development (e.g. Veneziano,

2004). Alternatively, children may develop their own standards for parental behavior (Rowe, 1981). If the participating families are again considered to have a higher rate of positive parent-child interactions, it may be that the children have developed a similar set of standards against which both maternal and paternal behaviors are judged.

Contrary to expectations, the association is slightly stronger for fathers. This, however, may pertain to specifically the facets of parental behavior measured by the index employed in his study. This may also be the reason for the same directionality of the maternal PB-LI association as the paternal one. Notably, the Vanyukov *et al.* (2007) study's findings pertain to the categorical diagnoses of childhood behavioral disorders rather than the continuous index employed herein. This index, the LI, may provide more consistent data and ensures a higher power of analysis than categorical data.

A highly significant correlation between PB scores of mothers and fathers is consistent with findings by others, e.g., Rowe (1981) who also found similarly strong relationships between perception of maternal and paternal behavior. This relationship may be reflective of homogamy, particularly due to assortative mating, for psychological characteristics determining parenting style. Phenotypic assortment can increase the genetic and/or environmental covariance between parent-offspring pairs because the process of assortment generates correlations between the sources of variance in one spouse with those of the other spouse (Maes *et al.*, 2006). As indicated by the moderation of this relationship by the child's sex (sons perceive maternal and paternal behavior more similarly than daughters), PB as well as parental correlations for this index are likely contributed by parent-child interactions, which are not possible to estimate within the framework of this research. Other aspects of the PB-LI system are, however, amenable to analysis.

The present study sought to evaluate genetic and environmental contributions to the variation in LI and PB and the relationship between them. Potentially, the sources of this correlation are numerous and include direct and reciprocal influence of the variables on each other, genetic and/or environmental correlation, and contribution of PB as a measure of parental influence to an environmental component of the LI variance. Results of structural equation modeling analysis indicate environmental sources of variation in PB, whereas LI has high heritability and no apparent common environment variance. In addition to indicating the genetic sources of phenotypic variance, the latter finding suggests that the age variation in the sample, which may mimic shared environmental effects (Neale & Maes, 2004), did not bias the estimates. By exclusion of genetic and shared environment variance that would be common to LI and PB, this limits possibilities and suggests that a likely common source of variance is the unique environment component present for both indices. It is also possible that a more complex architecture of the relationships, including genotype-environment and sex-dependent interactions, is involved, causing the lack of fit of the tested bivariate structural equation models specifying correlation between unique environmental components of LI and PB variances.

The results of the univariate analysis of the LI validate the index as a measure of transmissible liability to SUD, supporting a novel methodology for quantitative evaluation of the risk for relatively late onset disorders in the absence of disorder symptoms, or before symptoms develop. Importantly, these results also suggest that the transmissibility of SUD liability as indicated by the child's behavioral indicators is entirely due to additive genetic mechanisms. This finding is consistent with the results of authoritative twin studies that addressed manifest SUD liability using categorical SUD diagnosis as phenotypic variable (Kendler *et al.*, 2003; Tsuang *et*

al., 1998). The high heritability of the index underscores its utility for genetic and other etiology research pertaining to SUD risk.

In the same vein, the purely environmental composition of PB variance is supportive of this measure's utility as an environmental index. Its relationship with LI, consistent with parental influence on non-shared environment, points to a potentially malleable component of risk variation. Its importance is underscored by homogamy (possibly due to assortative mating), or, alternatively, by similarity in the perception of fathers' and mothers' behavior by the child. This finding also suggests that paternal parenting is of no less importance to behavioral development related to SUD risk than maternal parenting. The continuation of this research, taking into consideration additional environmental measures, developmental outcomes, molecular genetic data, and heterogeneity due to age and sex, will clarify the complex architecture of SUD risk.

7.0 CONCLUSIONS

In this study, we evaluated the relationship between perception of parental behavior and risk for SUD as well as the contributions to individual phenotypic variance in these traits utilizing a biometrical genetic approach and the twin method. Results from this study include:

1. The Pittsburgh Registry of Infant Multiplets has continued to grow in number of participating families, by 16% over the past 19 months, further establishing it as a source of participants for biometrical genetics research studies.

2. The child's perception of parental behavior was significantly associated with risk for SUD, and was not significantly different for male and female children, or for maternal versus paternal behavior. Parental behavior and the liability index were positively correlated, which may be a reflection of the study population itself; these children may have a higher (i.e. more positive) background perception of their parents.

3. Indices of maternal and paternal behavior were moderately correlated, suggesting the presence of homogamy, possibly due to assortative mating.

4. The liability index was found to be highly heritable ($h^2 = 0.79$), whereas the variation in PB, for both mothers and fathers, is explained by shared and unique environment. This supports validity of the LI as a measure for SUD risk, and the PB as a useful measure of the child's environment.

Future research in this area of risk for substance use disorders is warranted. A continuation of the present study conducted using a longitudinal study design, possibly utilizing the PRIM participants, would further inform the results. Effects of change over time, specifically how SUD risk and parent-child interactions evolve as the children get older, can be evaluated with this design. Genetic studies to investigate possible candidate genes and associations to SUD risk will continue to characterize this inheritance of this trait.

7.1 PUBLIC HEALTH SIGNIFICANCE

Substance use disorders are a major concern for public health, particularly in the context of prevention. This study provides information about likely precursors to SUD. These precursors include behavioral traits of the child measured by the LI, as well as the environment that is reflected in perception of parental behavior (PB). A goal of this study was to learn the possible mechanisms of the LI-PB association (e.g., environmental parental impact and/or reciprocal parent-child interaction), to further inform intervention strategies that might be developed for targeted populations, such as parenting interventions for families of children with behavior problems. For instance, results of this study indicate that the LI is a valid measure of the risk for SUD based on behavioral indicators in the child. This measure's utility in the realm of prevention is apparent in that it can assess the risk for SUD before symptom onset. This makes the LI suitable for use as a tool to identify at-risk children, before drug use begins and target these individuals for prevention programs. The results also suggest that the influence of parental behavior is an environmental influence on a child's liability for substance use disorders. Though the findings of this study (i.e. positive correlation between perception of parental behavior and

LI) are unexpected and counterintuitive, they nonetheless underscore the importance of the parent-child interaction for the risk to develop SUD. With further delineation of the associations of and relationship between these risk factors to SUD, coupled with genetic analyses of SUD candidate genes, an understanding of the ontogenesis of SUD will begin to develop and lead to the advancement of effective strategies to combat this disorder.

APPENDIX A

ZYGOSITY QUESTIONNAIRE

Are your twins of opposite sex?
☐ YES ☐ NO
If YES, *do not continue*
Are your twins
☐ boys or ☐ girls?

PLEASE NOTE: NON IDENTICAL TWINS ARE OFTEN CALLED FRATERNAL TWINS

1. Have you ever been told by a *health professional* (for example doctor; nurse consultant) that your twins are identical or non-identical? *(PLEASE CHECK ONE)*
   ☐ YES, identical ☐ YES, non-identical ☐ NO

   If YES, why did they think this?

2. Do *you* think your twins are identical or non identical? *(PLEASE CHECK ONE)*
   ☐ Identical ☐ Non-identical

   Why do you think this?

3. Are there differences in the *shade* of your twins' hair? *(PLEASE CHECK ONE)*
   ☐ None ☐ Only a slight difference ☐ Clear difference

   If there is a difference, please describe:

4. Are there differences in the *texture* of your twins' hair (fine or coarse, straight or curly, etc.)? *(PLEASE CHECK ONE)*
   ☐ None ☐ Only a slight difference ☐ Clear difference

   If there is a difference, please describe:

5. Are there differences in the color of your twins' eyes? *(PLEASE CHECK ONE)*

☐ None ☐ Only slight difference ☐ Clear difference

If there is a difference, please describe:

6. Are there differences in the shape of your twins' ear lobes? *(PLEASE CHECK ONE)*

☐ None ☐ Only slight difference ☐ Clear difference

If there is a difference, please describe:

7. Did the twins' teeth begin to come through at about the same time? *(PLEASE CHECK ONE)*

☐ The twins had matching teeth on the same side come through within a few days of each other

☐ The twins had matching teeth on opposite sides come through within a few days of each other

☐ The twins had different teeth come through within a few days of each other

☐ The twins' first teeth did not come through within a few days of each other

☐ The twins' teeth have not come through yet

8. Do you know of any physical differences between your twins that are not clear from looking at them (e.g. differences in internal organs)?

☐ YES ☐ NO

If YES, please describe:

9. Do you know your twins' ABO blood group and Rhesus (Rh) factors? *(PLEASE CHECK ONE)*

☐ YES ☐ NO

If YES, are they: *(PLEASE CHECK A BLOOD GROUP AND RHESUS FACTOR FOR EACH TWIN)*

1st born ☐A ☐B ☐AB ☐0 ☐Rh+ ☐Rh-

2nd born ☐A ☐B ☐AB ☐0 ☐Rh+ ☐Rh-

10. If there are differences between your twins, are they because of anything like problems at birth; an accident; or illness? *(PLEASE CHECK ONE)*

☐ YES ☐ NO ☐ Don't Know ☐ There are no differences

If YES, please describe:

11. As your twins have grown older, has the likeness between them: *(PLEASE CHECK ONE)*

☐ Remained the same ☐ Become less ☐ Become more

12. When looking at a new photograph of your twin, can you tell them apart (without looking at their clothes or using other clues)? *(PLEASE CHECK ONE)*

☐ YES, easily
☐ YES, but it is hard sometimes
☐ NO, I often confuse them in photographs

13. Do any of the following people ever mistake your twins for each other?
(PLEASE CHECK ONE FOR EACH GROUP OF PEOPLE)

Other parent of the twins
☐ YES, often
☐ YES, sometimes
☐ Rarely or never
☐ No other parent

Older brothers and sisters
☐ YES, often
☐ YES, sometimes
☐ Rarely or never
☐ No older brothers or sisters

Other relatives
☐ YES, often
☐ YES, sometimes
☐ Rarely or never

Babysitter/day care
☐ YES, often
☐ YES, sometimes
☐ Rarely or never

Parents' close friends
☐ YES, often
☐ YES, sometimes
☐ Rarely or never

Parents' casual friends
☐ YES, often
☐ YES, sometimes
☐ Rarely or never

People meeting the twins for the first time
☐ YES, often
☐ YES, sometimes
☐ Rarely or never

14. If the twins are ever mistaken for one another; does this ever occur when they are together? *(PLEASE CHECK ONE)*

☐ Yes, often
☐ Yes, sometimes
☐ No, almost never
☐ They are not mistaken for one another

15. Would you say that your twins… *(PLEASE CHECK ONE)*

☐ are as physically alike as "two peas in a pod" (virtually the same)
☐ are as physically alike as brothers and sisters are
☐ do not look very much alike at all

APPENDIX B

CHILDREN'S REPORT ON PARENTAL BEHAVIOR INVENTORY (REVISED - PB)

On the following pages you will find a series of statements, which a person might use to describe their parents. Read each statement carefully and decide which answer from the choices provided most closely describes the way your parents have acted towards you. Choose one answer for each question.

2 = Very True
1 = Somewhat true
0 = Not at all true

1a. My FATHER likes to talk to me and be with me much of the time.
1b. My MOTHER likes to talk to me and be with me much of the time
2a. My FATHER is always thinking of things that will make me happy.
2b. My MOTHER is always thinking of things that will make me happy.
3a. My FATHER thinks I don't appreciate him when I don't obey.
3b. My MOTHER thinks I don't appreciate her when I don't obey.
4a. My FATHER gives me a lot of care and attention.
4b. My MOTHER gives me a lot of care and attention.
5a. My FATHER says some day when I grow up I'll be punished for the bad things I do now.
5b. My MOTHER says some day when I grow up I'll be punished for the bad things I do now.
6a. My FATHER thinks and talks about my bad behavior long after it is over.
6b. My MOTHER thinks and talks about my bad behavior long after it is over.
7a. My FATHER makes me feel like the most important person in his life.
7b. My MOTHER makes me feel like the most important person in her life.
8a. My FATHER says that someday I'll be sorry that I wasn't better as a child.
8b. My MOTHER says that someday I'll be sorry that I wasn't better as a child.
9a. My FATHER enjoys staying at home with me more than going out with friends.
9b. My MOTHER enjoys staying at home with me more than going out with friends.
10a. My FATHER thinks that any bad behavior is very serious and will affect my life when I grow up.
10b. My MOTHER thinks that any bad behavior is very serious and will affect my life when I grow up.
11a. My FATHER spends almost all of his free time with the children.
11b. My MOTHER spends almost all of her free time with the children.
12a. My FATHER says I don't appreciate all he has done for me when I don't do as told.
12b. My MOTHER says I don't appreciate all she has done for me when I don't do as told

13a. My FATHER is liked by my friends.
13b. My MOTHER is liked by my friends.
14a. My FATHER treats me very warmly.
14b. My MOTHER treats me very warmly.
15a. My FATHER is fun to be with.
15b. My MOTHER is fun to be with.
16a. My FATHER breaks promises to me.
16b. My MOTHER breaks promises to me.
17a. My FATHER is often sad.
17b. My MOTHER is often sad.
18a. My FATHER treats me very unfairly at times.
18b. My MOTHER treats me very unfairly at times.
19a. My FATHER cares about me a lot.
19b. My MOTHER cares about me a lot.
20a. My FATHER is more concerned with his own problems than with mine.
20b. My MOTHER is more concerned with her own problems than with mine.

APPENDIX C

LIABILITY INDEX

Description of Items (45 Items)

CHILD BEHAVIOR CHECKLIST: MOTHER REPORTING ON INDEX

Below is a list of items that describes children and youth. For each item that describes your child now or within the past 6 months, please circle the correct response that applies to your child.
0 = Not True, 1 = Somewhat or Sometimes True, 2 = Very True or Often True

1. Destroys things belonging to his/her family or others
2. Disobedient at school
3. Steals at home

TARTER CHECKLIST : MOTHER REPORTING ON IC

Answer each question as to presence of the characteristic prior to the age 13
1 = Yes, 0 = No, -2 = Don't know

4. Lying
5. Stealing

DIAGNOSTIC INSTRUMENT CHILDREN: INDEX REPORTING ON SELF

0= NO, 1 = Yes, -2 = Don't Know

6. Did you often annoy people on purpose to get even?
7. Did you often do things to annoy people like grabbing another child's hat?

DIAGNOSTIC INSTRUMENT CHILDREN: MOTHER REPORTING ON INDEX

0= NO, 1 = Yes, -2 = Don't Know

8. Did you often do things to annoy people like grabbing another child's hat?
9. Did you often annoy people on purpose to get even?

DYSREGULATION INVENTORY SCALE: INDEX ON SELF

Please answer whether you agree with the statement below by choosing the best response that applies to you:
0 = Never true, 1 = Occasionally true, 2 = Mostly true, 3 = Always true

10. I interrupt on people when they are speaking.

DYSREGULATION INVENTORY SCALE: MOTHER ON INDEX
Please answer whether you agree with the statement below by choosing the best response that applies to your son/daughter
0 = Never true, 1 = Occasionally true, 2 = Mostly true, 3 = Always true

11. He/she interrupts on people when they are speaking.

CONNER'S RATING SCALE: TEACHER REPORTING ON INDEX
Choose the number from the choices provided that best describes how each statement applies to the child
0 = Not at all, 1 = Just a little, 2 = Pretty much, 2 = Pretty much

12. Excitable, Impulsive

DISRUPTIVE BEHAVIOR DISORDER SCALE: TEACHER REPORTING ON INDEX
For each of the following statements choose the number that best describes the behavior of this child. Please choose "Don't know" for any question which you don't know the answer because you have never had the opportunity to observe that behavior in the child
0 = Not at all, 1 = Just a little, 2 = Pretty much, 3 = Very much, -2 = Don't know

13. ...often engages in physically dangerous activities without considering possible consequences (not for the purpose of thrill-seeking), e.g. runs into street without looking
14. ...has difficulty awaiting turn in games or group situations
15. ...often blurts out answers to questions before they have been completed
16. ...often interrupts or intrudes on others, e.g., butts into other children's games

DIAGNOSTIC INSTRUMENT CHILDREN: INDEX REPORTING ON SELF

B. Rate past column; If definite diagnosis of ADHD:
C. Ask how he has felt in the past 6 months

If he has felt better or worse:

D. Ask questions about the past 6 months

If he has felt the same:

F. Copy the past column ratings on the current column

17. Did you blurt out answers to questions before they had been completed or did you get into trouble because you would rush into things without thinking?

DIAGNOSTIC INSTRUMENT CHILDREN: MOTHER REPORTING ON INDEX

B. Rate past column; If definite diagnosis of ADHD:
C. Ask how he has felt in the past 6 months

If he has felt better or worse:

D. Ask questions about the past 6 months

If he has felt the same:

F. Copy the past column ratings on the current column

18. Did you have difficulty staying in line in the supermarket or waiting for your turn while you were playing with other children?
19. Did you blurt out answers to questions before they had been completed or did you get into trouble because you would rush into things without thinking?

20. Did you get into trouble a lot for talking out of turn in school or talking without the teacher calling on you or for bothering people?
21. Did you get into trouble because you would do things without thinking about them first, for example running into the street without looking?
22. Did you skip classes or school without excuse?

TARTER CHECKLIST: MOTHER REPORTING ON IC
Answer each question as to presence of the characteristic prior to the age 13
23. Impulsive

CHILD BEHAVIORAL CHECKLIST: MOTHER REPORTING ON INDEX
Below is a list of items that describes children and youth. For each item that describes your child now or within the past 6 months, please circle the correct response that applies to your child.
0 = Not True, 1 = Somewhat or Sometimes True, 2 = Very True or Often True
24. Impulsive or acts without thinking

CHILD BEHAVIORAL CHECKLIST (TEACHER'S)
Below is a list of items that describes pupils. For each item that describes the **pupil now or within the past 2 months**. Please answer all items as well as you can, even if some do not seem to apply to this pupil.
0 = Not True, 1 = Somewhat or Sometimes True, 2 = Very True or Often True
25. Impulsive or acts without thinking
26. Talks out of turn

CHILD BEHAVIORAL CHECKLIST: MOTHER REPORTING ON INDEX
Below is a list of items that describes children and youth. For each item that describes your child now or within the past 6 months, please circle the correct response that applies to your child.
0 = Not True 1 = Somewhat or Sometimes True 2 = Very True/Often True
27. Bites fingernails
28. Picks nose, skin or other parts or body

DIMENSIONS OF TEMPERAMENT SURVEY –REVISED (CHILD)
HOW TO ANSWER: On the following pages are some sentences. They are about how children like you may behave. Some of the sentences may be true of how you behave and others may not be true for you. For each sentence we would like you to say if the sentence is usually true for you, in more true than false for you, is more false than true for you, or is usually false for you. There is no "right" or "wrong" answer because all children behave in different ways. All you have to do is answer what is true for YOU.
1 = Usually false, 2 = More false than true, 3 = More true than false, 4 = Usually true
29. I move a great deal in my sleep.
30. I don't move around much at all in my sleep.

DIMENSIONS OF TEMPERAMENT SURVEY –REVISED (MOTHER RE: CHILD)

HOW TO ANSWER: On the following pages are some sentences. They are about how children like you may behave. Some of the sentences may be true of how you behave and others may not be true for you. For each sentence we would like you to say if the sentence is usually true for you, in more true than false for you, is more false than true for you, or is usually false for you. There is no "right" or "wrong" answer because all children behave in different ways. All you have to do is answer what is true for YOU.

1 = Usually false, 2 = More false than true, 3 = More true than false, 4 = Usually true

31. My child moves a great deal in his/her sleep.
32. In the morning, my child is still in the same place as he/she was when he/she fell asleep.
33. My child doesn't move around much at all in his/her sleep.

DIMENSIONS OF TEMPERAMENT SURVEY –REVISED (CHILD)

HOW TO ANSWER: On the following pages are some sentences. They are about how children like you may behave. Some of the sentences may be true of how you behave and others may not be true for you. For each sentence we would like you to say if the sentence is usually true for you, in more true than false for you, is more false than true for you, or is usually false for you. There is no "right" or "wrong" answer because all children behave in different ways. All you have to do is answer what is true for YOU.

1 = Usually false, 2 = More false than true, 3 = More true than false, 4 = Usually true

34. I get hungry about the same time each day.
35. I usually eat the same amount each day.
36. I eat about the same amount at supper from day to day.
37. My appetite seems to stay the same day after day.

DIMENSIONS OF TEMPERAMENT SURVEY –REVISED

HOW TO ANSWER: On the following pages are some sentences. They are about how children like you may behave. Some of the sentences may be true of how you behave and others may not be true for you. For each sentence we would like you to say if the sentence is usually true for you, in more true than false for you, is more false than true for you, or is usually false for you. There is no "right" or "wrong" answer because all children behave in different ways. All you have to do is answer what is true for YOU.

1 = Usually false, 3 = More true than false, 2 = More false than true, 4 = Usually true

38. It takes my child a long time to get used to a new thing in the home.
39. It takes my child a long time to adjust to new schedules.
40. Changes in plans make my child restless.
41. My child resists changes in routine.

CHILD BEHAVIORAL CHECKLIST (TEACHER'S)
Below is a list of items that describes pupils. For each item that describes the pupil now or within the past 2 months. Please answer all items as well as you can, even if some do not seem to apply to this pupil.
0 = Not True, 1 = Somewhat or Sometimes True, 2 = Very True or Often True

42. Physical problems without known medical causes
    a) Aches or pains (not stomach or headaches)
    b) Headaches

DIAGNOSTIC INSTRUMENT CHILDREN
IX. RECURRENT THOUGHTS OF DEATH
1 = Yes, 2 = NO

43. Were things so bad that you were thinking a lot about death or that you would be better off dead?

CHILD BEHAVIORAL CHECKLIST (TEACHER'S)
Below is a list of items that describes pupils. For each item that describes the pupil now or within the past 2 months. Please answer all items as well as you can, even if some do not seem to apply to this pupil.
0 = Not True, 1 = Somewhat or Sometimes True, 2 = Very True or Often True

44. Deliberately harms self or attempts suicide

BIBLIOGRAPHY

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders,* Fourth Edition, Text Revision. Washington, DC, American Psychiatric Association.

Ausubel, DP, Balthazar, EE, Rosenthal, I, Blackman LS, Schpoont, SH, & Welkowitz, J. (1954). Perceived parent attitudes as determinants of children's ego structure. *Child Development, 25*, 173-183.

Baumrind, D. (1991). The influence of parenting style on adolescent competence and substance use. *The Journal of Early Adolescence, 11*, 56-95.

Burt, SA, Krueger, RF, McGue, M, & Iacono, W. (2001). Sources of covariation among attention-deficit/hyperactivity disorder, oppositional defiant disorder, and conduct disorder. *Journal of Abnormal Psychology*, 110, 516-525.

Burt, SA, Krueger, RF, McGue, M, Iacono, W. (2003). Parent-child conflict and the comorbidity among childhood externalizing disorders. *Archives of General Psychiatry, 60*, 505-513

Campo, AT & Rohner, RP. (1992). Relationships between perceived parental acceptance-rejection, psychological adjustment, and substance abuse among young adults. *Child Abuse & Neglect, 16*, 429-440.

Centers for Disease Control and Prevention. (2007). *2005 assisted reproductive technology success rates: National summary and fertility clinic reports*. Atlanta: Centers for Disease Control and Prevention.

Cohen, DJ, Dibble, E, & Grawe, JM. (1977). Parental style: Mothers' and fathers' perceptions of their relations with twin children. *Archives of General Psychiatry, 34*, 445-451.

Collins, WA & Russell, G. (1991). Mother-child and father-child relationships in middle childhood and adolescence: A developmental analysis. *Developmental Review, 11*, 99-136.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16(3)*, 297-334.

Evans, DM, Gillespie, NA, & Martin, NG. (2002). Biometrical Genetics. *Biological Psychology, 61*, 33-51.

Falconer, DS. (1965). The inheritance of liability to certain diseases, estimated from the incidence among relatives. *Annals of Human Genetics, 29*, 51-76.

Fisher, RA. (1918). The correlation between relatives on the supposition of Mendelian inheritance. *Philosophical Transactions of the Royal Society of Edinburgh, 2*, 399-433.

Galton, F. (1875). The history of twins, as a criterion of the relative powers of nature and nurture. *Fraser's Magazine, 12*, 566-576.

Goldin, PC. (1969). A review of children's reports of parent behaviors. *Psychological Bulletin, 71*, 222-236.

Gerra, G, Zaimovic, A, Garofano, L, Ciusa, F, Moi, G, Avanzini, P, *et al*. (2007). Perceived parenting behavior in the childhood of cocaine users: Relationship with genotype and personality traits. *American Journal of Medical Genetics Part B, 144B*, 52-57.

Hamilton, BE, Minino, AM, Martin, AJ, Kochanek, KD, Strobino, DM, & Guyer, B. (2007). Annual summary of vital statistics: 2005. *Pediatrics, 119*, 345-360.

Hoekstra, C, Zhao, ZZ, Lambalk, CB, Willemsen, G, Martin, NG, Boomsma DI, & Montgomery, GW. (2008). Dyzygotic Twinning. *Human Reproduction Update, 14*, 37-47.

Jessor, R & Jessor, SL. (1973). The perceived environment in behavioral science. *American Behavioral Scientist, 16*, 801-828.

Kendler, KS. (1996). Parenting: A genetic-epidemiologic perspective. *American Journal of Psychiatry, 153*, 11-20.

Kendler, KS & Baker, JH. (2007). Genetic influences on measures of the environment: A systematic review. *Psychological Medicine, 37*, 615-626.

Kendler, KS, Myers, J, & Prescott, CA. (2007). Specificity of genetic and environmental risk factors for symptoms of cannabis, cocaine, alcohol, caffeine, and nicotine dependence. *Archives of General Psychiatry*, 64, 1313-1320.

Kendler, KS, Jacobson, KC, Prescott, CA, & Neale, MC. (2003). Specificity of genetic and environmental risk factors for use and abuse/dependence of cannabis, cocaine, hallucinogens, sedatives, stimulants, and opiates in male twins. *American Journal of Psychiatry, 160*, 687-695.

Kendler, KS, Neale, MC, Kessler RC, Heath, AC, & Eaves, LJ. (1992). Major depression and generalized anxiety disorder: Same genes, (partly) different environments? *Archives of General Psychiatry, 49*, 716-722.

Kirisci, L, Dunn, MG, Mezzich, AC, & Tarter, RE. (2001). Impact of parental substance use disorder and child neglect severity on substance use involvement in male offspring. *Prevention Science, 2*, 241-255.

Lichtenstein, P, Ganiban, J, Neiderhiser, JM, Pederson, NL, Hannsson, K, Cederblad, M, Elthammar, O, & Reiss, D. (2003). Remembered parental bonding in adult twins: Genetic and environmental influences. *Behavior Genetics, 33*, 397-408.

Maes, HH, Neale, MC, Kendler, KS, Martin, NG, Heath, AC, & Eaves, LJ. (2006). Genetic and cultural transmission of smoking initiation: An extended twin kinship model. *Behavior Genetics, 36*, 795-808.

Magee-Womens Hospital. (2007). http://www.upmc.com/HospitalsFacilities/Magee/. UPMC. Accessed February 20, 2008.

Margolies, PJ & Weintraub, S. (1977). The revised 56-item CRPBI as a research instrument: Reliability and factor structure. *Journal of Clinical Psychology, 33*, 472-476.

Martin, N, Boomsma, D, & Machin, G. (1997). A twin-pronged attack on complex traits. *Nature Genetics, 17*, 387-392.

Mussen, P & Distler, L. (1959). Masculinity, identification, and father-son relationships. *Journal of Abnormal and Social Psychology, 59*, 350-356.

Nadder, TS, Silberg, JL, Maes, HH, & Meyer, JM. (1998). Genetic effects on ADHD symptomatology in 7- to 13-year-old twins: Results from a telephone survey. *Behavior Genetics, 28*, 83-99.

National Institute on Drug Abuse. (2003). *Drug use among racial/ethnic minorities*. Bethesda, MD: NIH Publication #03-3888.

Neale, M & Cardon, L. (1992). Methodology for Genetic Studies of Twins and Families. Kluwer Academic, Fordrecht.

Neale, MC, Boker, SM, Xie, G, & Maes, HH. (2003). *Mx: Statistical Modeling*. VCU Box 900126, Richmond, VA 23298: Department of Psychiatry. 6th Edition.

Neale, MC & Maes, HHM. (2004). *Methodology for Genetic Studies of Twins and Families*. Dordrecht, the Netherlands: Kluwer Academic Publishers B.V.

Neiderhiser, JM, Reiss, D, Pederson, NL, Lichtenstein, P, Spotts, EL, Hansson, K, Cederblad, M, & Elthammer, O. Genetic and environmental influences on mothering of adolescents: A comparison of two samples. *Developmental Psychology, 40*, 335-351.

Nichols, RC & Bilbro, WC. (1966). Diagnosis of twin zygosity. Acta Genetica et Statistica Medica, 16, 265-275.

O'Conner, TG, Hetherington, EM, Reiss, D, & Plomin, R. (1995). A twin-sibling study of observed parent-adolescent interactions. *Child Development, 66*, 812-829.

Pears, K, Capaldi, DM, & Owen, LD. (2007). Substance use risk across three generations: The roles of parent discipline practices and inhibitory control. *Psychology of Addictive Behaviors, 21*, 373-386.

Pike, A & Plomin, R. (1997). A behavioural genetic perspective on close relationships. *International Journal of Behavioral Development, 21*, 647-667.

Plomin, R, DeFries, JC, & Loehlin, JC. (1977). Genotype-environment interaction and correlation in the analysis of human behavior. *Psychological Bulletin, 84*, 309-322.

Plomin, R, Reiss, D, Hetherington, EM, Howe, GW. (1994). Nature and nurture: Genetic contributions to measures of the family environment. *Developmental Psychology, 30*, 32-43.

Posthuma, D, Beem, AL, de Geus, EJC, van Baal, GCM, von Hjelmborg, JB, Iachine, I, & Boomsma, DI. (2003). Theory and practice in quantitative genetics. *Twin Research, 6,* 361-376.

Rask, K, Astedt-Kurki, P, Paavilainen, E, & Laippala, P. (2003). Adolescent subjective well-being and family dynamics. *Scandinavian Journal of Caring Sciences, 17*, 129-138.

Raskin, A, Boothe, HH, Reatig, NA, Schulterbrandt, JG, & Odle, D. (1971). Factor analysis of normal and depressed patients' memories of parental behavior. *Psychological Reports, 29*, 871-879.

Rende, RD, Slomkowski, CL, Stocker, C, Fulker, DW, & Plomin, R. (1992). Genetic and environmental influences on maternal and sibling interaction in middle childhood: A sibling adoption study. *Developmental Psychology, 28*, 484-490.

Roe, A & Siegelman, M. (1963). A parent-child relations questionnaire. *Child Development, 34*, 355-369.

Rohner, RP & Britner, PA. (2002). Worldwide mental health correlates of parental acceptance-rejection: Review of cross-cultural and intracultural evidence. *Cross-Cultural Research, 36*, 16-47.

Rohner, RP & Rohner, EC. (1980). Antecedents and consequences of parental rejection: A theory of emotional abuse. *Child Abuse and Neglect, 4*, 189-198.

Rowe, DC. (1981). Environmental and genetic influence on dimensions of perceived parenting: A twin study. *Developmental Psychology, 17*, 203-208.

Rowe, DC. (1983). A biometrical analysis of perceptions of family environment: A study of twin and singleton sibling kinships. *Child Development, 54*, 416-423.

Rutter, M & Silberg, J. (2002). Gene-environment interplay in relation to emotional and behavioral disturbance. *Annual Reviews in Psychology, 53*, 463-490.

Scarr, S & McCartney, K. (1983). How people make their own environments: A theory of genotype→environment effects. *Child Development, 54*, 424-435.

Schaefer, ES. (1965). Children's reports of parental behavior: An inventory. *Child Development, 36*, 413-424.

Schludermann, S & Schludermann, E. (1970). Replicability of factors in children's reports of parent behavior (CRPBI). *Journal of Psychology, 76*, 239-249.

Silberg, J, Rutter, M, Meyer, J, Maes, H, Hewitt, J, Simonoff, E, *et al*. (1996). Genetic and environmental influences on the covariation between hyperactivity and conduct disturbance in juvenile twins. *Journal of Child Psychology and Psychiatry, 37*, 801-816.

Stadelman, S, Perren, S, von Wyl, A, & von Klitzing, K. (2007). Associations between family relationships and symptoms/strengths at kindergarten age: What is the role of children's parental representations? *Journal of Child Psychology and Psychiatry, 48*, 996-1004.

Steinberg, L, Lamborn, SD, Darling, N, Mounts, NS, & Dornbusch, SM. (1994). Over-time changes in adjustment and competence among adolescents from authoritative, authoritarian, indulgent, and neglectful families. *Child Development, 65*, 754-770.

Strassberg, M, Peters, K, Marazita, M, Ganger, J, Watt-Morse, M, Murrelle, L, Tarter, R, & Vanyukov, M. (2002). *Twin Research, 5*, 499-501.

Tsuang, MT, Lyons, MJ, Meyer, JM, Doyle, T, Eisen, SA, Goldberg, J, *et al*. (1998). Co-occurrence of abuse of different drugs in men: The role of drug-specific and shared vulnerabilities. Archives of General Psychiatry, 55, 967-972.

van den Bree, MBM, Johnson, EO, Neale, MC, & Pickens, RW. (1998). Genetic and environmental influences on drug use and abuse/dependence in male and female twins. *Drug and Alcohol Dependence, 52*, 231-241.

Vanyukov, MM, & Tarter, RE. (2000). Genetic Studies of Substance Abuse. *Drug and Alcohol Dependence, 59*, 101-123.

Vanyukov, MM, Kirisci, L, Tarter, RE, Simkevitz, HF, Kirillova, GP, Maher, BS, & Clark, DB. (2003a). Liability to substance use disorders: 1. A measurement approach. *Neuroscience and Biobehavioral Reviews, 27*, 507-515.

Vanyukov, MM, Kirisci, L, Tarter, RE, Simkevitz, HF, Kirillova, GP, Maher, BS, & Clark, DB. (2003b). Liability to substance use disorders: 2. A measurement approach. *Neuroscience and Biobehavioral Reviews, 27*, 517-526.

Vanyukov, MM, Maher, BS, Devlin, B, Kirillova, GP, Kirisci, L, Yu, L, & Ferrell, R. (2007). The MAOA promoter polymorphism, disruptive behavior disorders, and early onset substance use disorder: Gene-environment interaction. *Psychiatric Genetics, 17*, 323-332.

Veneziano, RA. (2004). Parental roles. In *Encyclopedia of Sex and Gender: Men and Women in the World's Cultures* (Vol. 1, pp. 78-90). New York: Kluwer Academic/Plenum Publishers.

Wagenmakers, E & Farrell, S. (2004). AIC model selection using Akaike weights. *Psychonomic Bulletin & Review, 11*, 192-196.

Walden, B, McGue, Iacono, WG, Burt, SA, & Elkins, I. (2004). Identifying shared environmental contributions to early substance use: The respective roles of peers and parents. *Journal of Abnormal Psychology, 113*, 440-450.

Young, SE, Stallings, MC, Corley, RP, Krauter, KS, & Hewitt, JK. (2000). Genetic and environmental influences on behavioral disinhibition. *American Journal of Medical Genetics; Neuropsychiatric Genetics, 96*, 684-695.

Young, SE, Rhee, SH, Stallings, MC, Corley, RP, & Hewitt, JK. (2006). Genetic and environmental vulnerabilities underlying adolescent substance use and problem use: General or specific? *Behavior Genetics, 36*, 603-615.

Zucker, RA. (2006). The developmental behavior genetics of drug involvement: Overview and comments. *Behavior Genetics, 36*, 616-625.