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The Early Growth and Development Study: Using the Prospective Adoption Design to Examine Genotype–Environment Interplay

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Abstract

The Early Growth and Development Study (EGDS) is a prospective adoption design consisting of 360 linked sets of birth parents, adoptive parents, and adopted children followed from 3 months postpartum through child age 7 years, and an additional 200 linked sets for whom recruitment is underway. The EGDS brings together the study of genotype–environment correlation (*r*GE) and Genotype x Environment (GxE) interaction to inform intervention development by examining mechanisms whereby family processes mediate or moderate the expression of genetic influences. Participants in the EGDS are recruited through domestic adoption agencies located throughout the United States of America. The assessments occur at 6-month intervals until child age 4-½ years and at ages 6 and 7, when the children are in their 1st and 2nd years of formal schooling (kindergarten and first grade). The data collection includes measures of child characteristics, birth and adoptive parent characteristics, adoptive parenting, prenatal exposure to drugs and maternal stress, birth parent and adopted child salivary cortisol reactivity, and DNA from all participants. The preliminary analyses suggest evidence for GxE interaction beginning in infancy. An intervention perspective on future developments in the field of behavioral genetics is described.

There is accumulating evidence indicating that children's heritable characteristics influence their parents' behavior towards them (Dunn, Plomin, & Daniels, 1986; Reiss, Neiderhiser, Netherington, & Plomin, 2000), a process known as evocative genotype–environment correlation (*r*GE). For example, heritable hostile behavior in adolescent adoptees evokes harsh discipline from adoptive parents (Ge et al., 1996), and children with antisocial birth parents elicit more negative controlling discipline from their adoptive parents than do children with non-antisocial birth parents (O'Connor, Deater-Deckard, Fulker, Rutter, & Plomin, 1998). In addition, parenting processes and family context are known to be central in the moderation of genetic influences on child behavior. Genotype x Environment (GxE) interaction effects have been found for a host of outcomes, including conduct disorder, depression, and substance use (Button, Scourfield, Martin, Purcell, & McGuffin, 2005; Cadoret, 1982; Cadoret & Cain, 1981; Cadoret, Cain, & Crowe, 1983; Cadoret et al., 1996; Cadoret, Yates, Troughton, Woodworth, & Sterwart, 1995). For example, Cadoret's work suggests that adolescents who have an antisocial birth parent and who are reared in an adoptive family with marital problems

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or psychopathology are at increased risk for aggressivity compared to adolescents with one or neither of these risks. Although the vast majority of GxE interaction studies have focused on individuals aged 5 years and older, GxE interactions are likely to be present in early childhood, when child behavior is amenable to environmental intervention (Fisher & Kim, 2007; Olds, Robinson, Song, Little, & Hill, 2005; Shaw, Dishion, Supplee, Gardner, & Arnds, 2006). However, adoption studies prospectively examining social processes during early childhood are quite rare, with the current study and the Colorado Adoption Project (Plomin & DeFries, 1985) being the only such studies of which we are aware.

The adoption design is a powerful method for detecting evocative *r*GE and GxE effects because adoption is a natural experiment in which children are reared in families where they are genetically unrelated to their caretakers (Haugaard & Hazan, 2003); therefore, the effects of children on their parents cannot result from shared genes. In the full adoption design (in which data are collected from linked birth parents, adoptive parents, and the adopted child), genetic influences are inferred from similarities between the birth parents and the child, and environmental influences are inferred from associations between the adoptive parents' behavior/family environmental factors and the child's behavior. When fundamental design assumptions are met, such as the lack of selective placement and negligible effects of contact between birth and adoptive parents, associations between adoptive parenting and birth parent characteristics are considered as reflecting the evocative *r*GE processes. As is described in the Future Directions section of this manuscript, the identification of specific evocative *r*GE and GxE processes can provide insight into potential intervention targets.

Overview of the Early Growth and Development Study

This report describes the design of and early results from the Early Growth and Development Study (EGDS; HD042608, NICHD, NIDA, and the Office of the Director, U.S. PHS), a prospective adoption study designed to examine specific features of family relationships that mediate or moderate the expression of genetic influences beginning in infancy. The investigation of GxE interaction effects and *r*GE can provide crucial information about malleable environmental processes that might reduce adverse genetic risk and child characteristics that buffer against environmental risk. Thus, a long-term goal of the EGDS is to systematically identify specific family processes and resiliency processes that could serve as malleable targets for future intervention studies.

The sample currently includes 360 linked sets of birth parents, adoptive parents, and adopted children (hereafter referred to as "adoption triads"). The infancy and toddlerhood assessments have been completed as part of the first phase of funding (2002–2007), and we are currently assessing participants in the preschool and school entry periods as part of the second phase of funding (2007–2012). An additional sample of 200 adoption triads is being recruited in a separate study (in which the recruitment and assessment methods mirror the original study) that will enhance the measurement of prenatal factors and add DNA collection for the full sample of 560 adoption triads (DA020585, NIDA, NIMH, and the Office of the Director, U.S. PHS). The EGDS investigative team is interdisciplinary, consisting of experts in developmental psychology, behavioral genetics, sociology, psychiatry, and preventive intervention.

The EGDS Aims

With an eye toward informing future intervention development, the EGDS has been focused on four primary aims. The first aim is to examine specific parenting and family environmental processes that *mediate* the expression of genetic influences on children's internalizing behavior, externalizing behavior, social competence, and school performance. We designed the EGDS to test whether genetically influenced child behaviors that evoke specific parenting practices could be identified (evocative *r*GE) and would subsequently amplify child behavior

and affect child adjustment. The second aim is to examine specific parenting processes and contextual factors that *moderate* genetic influences on children's internalizing behavior, externalizing behavior, social competence, and school performance. A set of specific parenting behaviors (e.g., harsh or noncontingent parenting) and contextual factors (e.g., adoptive parents' marital relations) are measured to assess the extent to which they moderate genetic risk and protective influences on internalizing behavior, externalizing behavior, social competence, and school performance (GxE interaction) during early childhood, amplifying child outcomes over time. The third aim is to identify the mechanisms of GxE interaction. We focus on dyadic interactions between the adoptive parent and adopted child to examine how, when, and why GxE interactions occur. GxE interactions are hypothesized to be explained by their effects on the reciprocal, genetically influenced processes between parent and child. Specifically, *child evocative GxE interactions* would be indicated when heritable characteristics of the child evoke more adverse or more favorable parental response in some types of family environments but not in others, and *child sensitivity GxE interactions* would be indicated when heritable characteristics make the child more sensitive to differences between favorable and adverse family environments. An illustration of the first three study aims and the EGDS conceptual model is provided in Leve et al. (2007). The fourth aim was implemented during the second phase of funding and includes an examination of early responding systems that are susceptible to both genetic and environmental influences and are thought to serve as precursors to the primary outcomes of interest. In this aim, executive function (a precursor to externalizing problems), early literacy skills (a precursor to school performance), and cortisol reactivity (a precursor to internalizing problems) are measured in children and birth parents. By focusing on family processes and child behavior beginning in infancy, the EGDS provides an opportunity to detect GxE and *r*GE processes as they develop.

Recruitment Methods

The current EGDS sample was recruited between January 2003 and January 2006 using a rolling recruitment procedure implemented by three recruitment sites in the United States: Mid-Atlantic (based at George Washington University), West/Southwest (based at the University of California, Davis), and Pacific Northwest (based at the Oregon Social Learning Center). The first step was the recruitment of adoption agencies into the study ($N = 33$ agencies in 10 states). The agencies reflected the range of US adoption agencies: public, private, religious, secular, open adoption philosophies, and more closed adoption philosophies. The EGDS participants currently reside in 45 states and 3 foreign countries due to individuals working with out-of-state adoption agencies and participant mobility. Each adoption agency appointed an agency liaison from their organization to perform the initial stages of recruitment into the study. The liaisons received recruitment training by the EGDS staff, and the agencies were provided an honorarium for their efforts assisting with recruitment.

Inclusion criteria

Five inclusion criteria were used in the EGDS: completion of a domestic adoption placement, placement of the baby within 3 months postpartum, placement within a nonrelative adoptive family, no known major medical conditions (e.g., extreme prematurity or extensive medical surgeries), and birth and adoptive parents were able to read or understand English at the eighth-grade level. All birth and adoptive families who met these inclusion criteria during the recruitment period were considered for enrollment.

Recruitment of birth mothers, adoptive families, and birth fathers

Approximately 4 weeks postplacement, the agency liaison mailed a letter describing the study to adoptive families who met the inclusion criteria. A study brochure and a "no contact" postcard (for the adoptive family to return if they *did not* wish to be contacted) were included.

Two weeks after the mailing, a liaison called each birth mother linked to an adoptive family that did not return a postcard. Once a birth mother had consented to being contacted by the study, a birth parent recruiter called her to invite her to participate in the study. After recruiting the birth mother, a separate recruiter contacted the adoptive family using the contact information provided by the agency and invited the family to participate. Once the birth mother and adoptive parents were recruited, a project staff member recruited the birth father using similar methods as were used in recruiting the birth mother. The EGDS has the largest sample of directly studied birth fathers in an adoption study and is the only study to assess birth fathers longitudinally; we have recruited and assessed birth fathers in 32% of our participating triads (n = 114).

The EGDS recruitment staff had low decline rates once a potential participants were contacted (2% of the birth mothers, 17% of the adoptive families, and 8% of the birth fathers declined once contacted by EGDS staff). However, some participants were not able to be located; most nonparticipation resulted from the inability of the agency or the study to locate and contact a potential participant (for detailed information about recruitment procedures and rates, see Leve et al., 2007).

Confidentiality of participation between birth mother and birth father is maintained such that neither the agency nor project staff shared information about birth parent study participation between participants. In addition, the study maintains a strict firewall such that different staff members are responsible for birth parent and adoptive parent contact within a given triad (in recruitment and assessment). As such, we attempt to ensure that the study will not in any way serve as a conduit of information between parties.

Sample Description

The EGDS sample includes 360 adoptive triads: 360 adopted children, 360 sets of adoptive parents, 359 birth mothers, and 114 birth fathers. The mean age of the adoption placement was 3 days (*SD* = 5 days). The adopted children's birth dates ranged from January 2003 to January 2006. Forty-three percent of the children were female. Demographic information regarding parent age, race, education, income, and the number of individuals living in the home at the time of the adoption placement is provided in Table 1. The adoptive parents had been married an average of 11.8 years (*SD* = 5.1 years), and 51% of the adoptive families had at least one additional child in the home at the time of the writing of this report (*Mdn* age of additional children = 5.6 years, range = newborn–20 years).

Although the demographic characteristics of the adoptive parents were more favorable than those of the birth parents (as in prior adoption studies; DeFries, Plomin, & Fulker, 1994), a systematic test of range restriction biases has shown negligible effects on estimates of heritability and the environment, even when range restriction was present (McGue et al., 2007). Further, the differences between birth family and adoptive family characteristics suggest the unique utility of adoption as a preventive intervention focused on children's sociodemographic environments.

Data Collection

Measurement for the EGDS has been guided by three principles: adherence to a theoretical model guiding the domains of assessment between birth parent, adoptive parents, and the adopted child; repeated assessments of birth parents to increase the reliability of genetic estimates (three in-person assessments) and of adoptive families to allow for estimates of stability and change (six in-person assessments); and utilization of a multimethod, multiagent assessment strategy.

Overview of assessment

The EGDS assessment includes the following: questionnaires, in-person interviews, telephone interviews, and standardized testing for birth and adoptive parents; observational interactions for adoptive families; standardized testing for adopted children; diurnal salivary cortisol collection for birth parents and adopted children; medical records collection for birth parents; school and teacher records collection for adopted children; and salivary DNA collection from all participants. The interviews include interviewer-administered questions and computer-assisted personal interview (CAPI) questions that are completed privately by participants on a laptop computer or on the project's secure website. The birth parents are assessed in person at 3–6 months, 18 months, and 54 months postpartum and via telephone at 12, 22, 30, 36, and 42 months postpartum. The adoptive families are assessed in person at child age 9, 18, 27, 54, 72, and 84 months and via telephone at child age 6, 12, 22, 36, 48, 60, and 78 months. The in-person assessments last 2–4 hours, and the telephone interviews last approximately 15 min.

In-person assessments

All birth parent in-person assessments are conducted in a location convenient for the participant (most often at home) and include CAPI questions, interviewer-administered questions, and mailed/web-based questionnaires (completed prior to the interview). The first interview (3–6 months) also includes a pregnancy history calendar (completed by birth mothers via CAPI) about the birth mother's drug use and other behaviors during each trimester of pregnancy. The second in person interview (18 months) is similar to the first interview, and additionally includes the Composite International Diagnostic Interview (Kessler & Üstün, 2004), an assessment of intelligence using two subscales from the Wechsler Adult Intelligence Scale (Wechsler, 1997), and a CAPI version of the antisocial personality and conduct disorder sections from the Diagnostic Interview Schedule (Robins et al., 2000). The third in-person interview (54 months) mirrors the second assessment but incorporates several executive functioning tasks and an analog decision-making task.

All adoptive family in-person assessments are conducted in the family's home. Each adoptive mother and father completes a set of questionnaires prior to the interview (in hard copy or via a secure website). During the visit, CAPI questions are administered to parents via a laptop computer, a series of videotaped interaction tasks are conducted (e.g., child temperament tasks, parent–child interaction tasks, and marital interaction tasks), a series of standardized tests are administered to the child (e.g., early literacy and executive function tasks), and an analog parenting task is completed by the parents.

Telephone interviews

The telephone interviews are coordinated to occur between the in-person assessments and serve as a means of maintaining rapport with participants to aid in retention. The birth parent telephone interviews focus primarily on general well-being and on contact with the adoptive family. The adoptive family telephone interviews focus primarily on general well-being, the adopted child's daily behavior and parenting, and contact with the birth parent(s).

Salivary cortisol collection

To assess diurnal cortisol patterns, cortisol samples are collected from adopted children following the 54-, 72-, and 84-month in-person assessments and from birth parents following the 54-month assessment. The collections occur 30 min after awakening and 30 min prior to sleep on 3 sequential weekdays (six collections in total at each assessment wave). The interviewer demonstrates the collection procedures and has the participants practice how to collect saliva during the in person visit. The procedure for collecting saliva samples involves the participant putting a piece of cotton in his/her mouth for 1 min and then spitting it into a

tube. The participants return the samples to us via a prepaid priority mail envelope provided by the study to be assayed at the Oregon Social Learning Center cortisol laboratory.

Teacher and school data collection

During the 54-, 72-, and 84-month assessments, data are collected from preschool (if the child is enrolled in any daycare setting), kindergarten, and first-grade teachers, respectively. Teachers complete questionnaires about child behavior, peer relations, instructional practices, and school demographics via a secure website. The children's school records are collected at the 72- and 84-month assessment to gauge reading performance.

DNA collection

A new aspect of EGDS is the collection of buccal cells for DNA extraction from all participants. DNA will be collected during one of the in-home assessments, and returned to the Pennsylvania State University for assaying. We plan to examine candidate genes with known associations with antisocial behavior, depression, anxiety, attention problems, and/or substance use. The DNA collection will allow for an examination of *specific* GxE interactions and correlations.

Statistical Power

To examine the power to test the primary hypotheses with the EGDS sample of 360 triads, we modeled several alternative values based on genetic and environmental effects in prior studies. Effect sizes for genetic effects were estimated to range from .10–.50 based on findings of birth parents' effects on adolescent adoptees (β = .31 and .42; Ge et al., 1996; O'Connor et al., 1998). Using a 92% retention rate (current retention rates are 93% for adoptive families, 92% for birth mothers, and 91% for birth fathers), we estimated whether the EGDS sample of 360 triads (N = 331 when a 92% retention rate is assumed) would be sufficient for detecting significant genetic and environmental main effects, significant G×E interaction effects, and model fit in SEM. Power analyses suggested that a sample of 331 triads would provide power well above .90 for detecting genetic and environmental main effects, power of .50–.98 for detecting GxE interaction effects, and power of .78–.93 for model testing in SEM, suggesting that the EGDS is sufficiently powered. Further, the inclusion of 200 additional triads (currently underway) will increase our ability to detect effects that are small in magnitude.

Results to Date

Participant enrollment was completed during Spring 2006, and data collection through child age 27 months was completed in June 2008. As of the writing of this report, assessments through age 60 months are underway, and the 72- and 84-month assessments have not yet begun. As is described below, the analyses to date focus on sample representativeness, openness and selective placement in the adoption, and a preliminary investigation of GxE interactions.

Sample representativeness

We sought to examine whether the EGDS sample was representative of the population from which it was drawn. Each participating adoption agency recorded the education, income, and age of all birth and adoptive parents who met the EGDS inclusion criteria during the study enrollment period. We compared the demographic information between triads who participated in the EGDS (N = 360 triads) with those of the eligible nonparticipants (N = 1169 triads available for analysis). As was reported elsewhere (Leve et al., 2007), only 2 of 11 comparisons reached statistical significance, and they proved trivial due to their small effect size. There were no significant demographic differences between birth mothers for whom birth fathers were recruited and birth mothers for whom birth fathers were not recruited.

Regional differences in sample characteristics were examined given possible variations across the three recruitment regions. We compared birth mother, birth father, adoptive mother, and adoptive father education level, income, and age by the three recruitment regions. Of the 33 comparisons, only 3 were significant ($p < .05$), and each showed a very small effect size. The ethnic distribution of participants was similar across regions. Taken together, these comparisons suggest the representativeness of the EGDS sample to the population from which it was drawn and the likely generalizability of results to families involved in domestic adoption placements throughout the country.

Openness and selective placement in the adoption

The adoption design rests on several assumptions about the separate influences of genetic and environmental influences on child development. For example, once intrauterine factors have been considered, similarities between the birth parent and adoptive child can be assumed to result from genetic factors. Adoption practices such as selective placement (agency matching of similar birth and adoptive parent characteristics) and openness (contact between birth and adoptive families) can pose a threat to these assumptions and bias model estimates.

To examine the potential effect of selective placement in the EGDS, we correlated birth parent characteristics with adoptive family characteristics that were unlikely to be influenced by evocative effects (e.g., demographic characteristics). Not one of these relationships was statistically significant. To examine the potential effect of openness, we created an openness composite comprised of birth mother, adoptive mother, and adoptive father reports of openness, the level of contact between the birth and adoptive parents (five scales ranging from 1 [*never*] to 5 [*daily*]) and the extent of knowledge about each other (six scales ranging from 1 [*a lot*] to 4 [*nothing*]). The results of these analyses suggested that the number of significant correlations between the openness composite and our birth parent and adoptive family measures approximated levels expected by chance, suggesting negligible impact of openness on model estimates. Together with the selective placement results, these analyses support the adoption design assumptions of minimal selective placement and minimal bias due to the level of openness in the EGDS sample, although we will continue to examine these processes as the sample matures.

We next empirically examined the agreement between birth mothers, adoptive mothers, and adoptive fathers about the level of openness, and the association between openness with satisfaction with the adoption process and with psychosocial adjustment (Ge et al., in press). Prior research has examined openness from either the birth or the adoptive parents' perspective, but not from dual perspective using a linked birth parent-adoptive parent sample. The results indicated that birth mothers and adoptive parents were in high agreement as to the level of openness in the adoption (r range = .66–.81). Further, the results of SEM analyses suggested that openness in adoption was significantly related to satisfaction with the adoption process among adoptive mothers, adoptive fathers, birth mothers, and birth fathers. In addition, higher levels of openness were positively associated with birth mothers' and birth fathers' postplacement adjustment as indexed by their self-reports and by the interviewers' impression of birth parent adjustment (Ge et al., in press).

A preliminary investigation of GxE interaction

Our first examination of GxE interaction involved an effort to understand the effects of early experience on the pathways to externalizing behavior. In these preliminary analyses, 9-month-old infants were observed during a frustration task in which an acrylic glass barrier was placed in front of the infant in a series of six 30-s intervals. For half of the trials, the child could play with an attractive toy (neutral trials); for the other half of the trials, the child could see but not touch the attractive toy (frustration trials). The child's attention during the frustration trials,

controlling for his/her attention level during the neutral trials, was hypothesized to serve as an early index of externalizing problems. Prior research has shown that infants who failed to shift attention away from frustrating events, an indication of an inability to adaptively manage frustration, exhibited increased aggressive behavior at age 2-½ years (Crockenberg, Leerkes, & Barrig Jo, 2008) and that at-risk children overattend to negative cues (Shackman, Shackman, & Pollak, 2007).

In the EGDS analyses, we hypothesized that birth mothers' externalizing behavior would serve as an index of genetic risk for externalizing problems and that adoptive parents' anxious/depressive symptoms would be a primary environmental mechanism associated with the child's inability to shift attention away during the frustration trials, perhaps because of the failure of anxious/depressed parents to model healthy emotion regulation for their child. Further, the combination of genetic risk and environmental risk was hypothesized to interact to further increase attention levels during the frustration trials (GxE interaction). The results from the SEM analyses supported the moderation hypotheses involving adoptive mothers' affective state but not those involving adoptive fathers' affective state, perhaps because of the likelihood of greater maternal involvement in child rearing. The path from birth mother externalizing problems to child attention to frustration was significant for families that were above the mean on adoptive mother anxiety/depression, $\beta = .35$, $p < .01$, and nonsignificant for families that were below the mean on adoptive mother anxiety/depression, $\beta = -.01$ (Leve et al., 2008). The pattern of environmental moderation of genetic influences on infant behavior held when substance use during pregnancy was considered. Although preliminary, this GxE interaction finding suggests that the interplay between genes and the environment begins very early in development; subsequent outcomes of these early GxE processes will be examined when later waves of the EGDS data have been completed.

Future Directions

Current funding from the National Institutes of Health supports in-person data collection of the EGDS participants through child age 7 years and supports the additional recruitment and assessment of 200 adoptive triads and the collection of DNA from all participants. As the data become complete for each wave of assessment, we will examine the primary hypotheses involving environmental mediation, environmental moderation, and mechanisms of environmental moderation of genetic effects cross-sectionally and longitudinally. Our planned analysis approach will be systematic, in which composite indices are formed for each prespecified domain of functioning for each participant type. In addition, whenever possible, we will include observational data, self-report data, and other-report data to minimize potential method variance problems. The resulting set of analyses will provide novel information about the early precursors to problem behavior and competency in young children. As is described above, the majority of information about genotype–environment interplay has involved twin samples where evocative effects cannot be readily teased apart, has included individuals aged 5 or older, and/or has not focused specifically on the parenting and social environment of the adoptive family and the dyadic interactions among family members. Thus, the EGDS offers a unique perspective on the interplay between family processes and genetic influences in early development.

Each avenue of our future work in behavioral genetics is guided by a single unifying goal: to apply the findings from the EGDS to inform future preventive interventions aimed at improving child and family well-being. A growing number of preventive intervention programs have undergone rigorous outcome evaluations using randomized trial designs, and many of these have produced moderate-to-strong, enduring effects on child and adolescent well-being (e.g., Botvin, Mihalic, & Grotpeter, 1998; Greenberg, Kusché & Mihalic, 1998; Kellam et al., 2008; Olds et al., 2004; Webster-Stratton & Taylor, 2001). Efficacious, cost-effective programs

range from those using a universal prevention approach to promote child well-being for all youth in a given setting to those using a selected or indicated prevention approach with youth at- risk for problems. Many of these interventions aim to strengthen specific parenting processes to reduce immediate or proximal risks in families and/or in classrooms and to directly improve child well-being and life skills. However, even within the context of effective intervention programs, not all youth and families improve during or following the intervention services (Kellam et al., 2008). Thus, even highly efficacious, cost-effective interventions can be improved upon to offer *all* children and families the optimal preventive intervention services.

We view the field of behavior genetics as a very important, untapped resource to aid in improving the efficacy of preventive interventions and service delivery programs. A given intervention might not be effective for all youth because of the interplay between the intervention services provided and genetic factors unique to the individual. Evidence from the field of human genetics is just emerging to suggest that validated interventions show differential effectiveness youth based on the child's genotype (Bakermans-Kranenburg, van IJzendoorn, Pijlman, Mesman, & Juffer, 2008). Consistent with our focus on improving the efficacy of intervention and service delivery by way of leveraging knowledge from behavioral genetics, we briefly describe three future directions facilitated by the EGDS.

The first future direction (which will be uniquely facilitated by the full sample of 560 EGDS adoption triads) is the disaggregation of genetic, prenatal drug exposure, and postnatal rearing environment effects on young children. The prospective adoption design provides unique leverage to this question in three ways: the postnatal environment is distinct from the prenatal environment, a child's genetic risk for substance use and maternal prenatal substance use can be classified, and effects on the child can be examined prospectively. In studies of biological families, this fine-grained separation of postnatal, prenatal, and genetic effects cannot be achieved. This research focus will provide novel information on how the postnatal rearing environment enhances or reduces risk to children engendered by birth parent drug use and on whether this risk is conferred by genetic or intrauterine mechanisms or by an interaction between the two. Once the underlying etiological factors contributing to children's poor outcomes related to birth parent substance use have been more precisely identified, intervention programs can more adeptly target the primary causes leading to child risk. For example, if children who are exposed to prenatal substance use but who are reared in healthy postnatal environments look similarly well-adjusted to children without prenatal substance use and if children with the dual risks of exposure to prenatal substance use and a maladaptive postnatal environment show the poorest adjustment, then a dual intervention that targets prenatal (to minimize prenatal drug use) and postnatal (to teach parents effective parenting styles) variables could enhance intervention effects. Conversely, if the combination of prenatal substance use and maladaptive postnatal rearing environment is no worse than either risk independently, then there might be more flexibility as to when effective interventions could be delivered for families with the dual constellation of risks.

A second future direction is the exploration of how genetic and environmental influences on child behavior can be traced through their influences on early responding systems. In the EGDS, we focus on three such systems that undergo significant maturation during the preschool period: emergent literacy, hypothalamic-pituitary-adrenal axis functioning, and executive functioning. Each system is influenced by genetic and environmental factors, and might thus moderate a child's effect on or sensitivity to the family environment. For example, genetic influences on executive functioning deficits might place a child at greater susceptibility to respond negatively to unstructured classroom environments, which would then increase that child's risk for developing clinical-level externalizing problems. The focus on early responding systems might allow us to capture the developmental process whereby genetic and environmental influences

coalesce early in development, prior to the onset of a specific disorder. Identifying such processes linked to the early responding systems might bring us closer to identifying malleable behaviors and family processes that could serve as precursors to subsequent psychopathology. Interventions could then be structured around these known precursors to prevent the onset of clinical-level problems.

A third future direction is the use of a behavior genetic design in tandem with the collection of DNA and the measurement of well-specified environmental processes. Currently, the fields of behavioral genetics and molecular genetics have been relatively independent; however, the integration of the two approaches within a single study expands the possibility of linking specific polymorphisms with specific genetically influenced behaviors early in development. As such, phenotypic behaviors known to be associated with specific polymorphisms can be identified and used as potential screening and identification procedures for preventive interventions and service delivery programs. In future decades, as the field of molecular genetics advances and more gene variants known to increase risk for mental health disorders are identified, understanding the link between a specific polymorphism and a genetically influenced phenotypic behavior might provide an important clinical and preventive tool. Social service agencies that want to apply the newest knowledge about genetic risks for disorders but do have access to their clients' DNA profile (for technological and ethical reasons) can leverage knowledge from studies that use a behavioral-molecular genetic approach to target phenotypic behaviors. Data from the EGDS will be used to evaluate associations between polymorphisms and genetically influenced behaviors (and the moderating or mediating effect of the environment on such behaviors) and could be directly applied to the translation from DNA to a risk behavior. Although such translational approaches are still years from being implemented and will involve significant ethical discussion, studies such as the EGDS and others described in this special issue will be in place as a resource as the field develops.

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Table 1

Demographics for Birth Parents and Adoptive Parents

Variable	BM	BF	AM	AF
Mean age (years)	23.83 +/− 6.12	25.31 +/− 7.42	36.96 +/− 5.55	37.89 +/− 5.93
Race (%)				
Caucasian	78	63	93	92
African-American	11	20	4	5
Hispanic/Latino	4	8	1	1
Multiethnic	5	5	2	2
Other[a]	2	4	1	1
Mean education level	5	5	9	9
Median annual household income	$14,000	$21,000	$119,000	
Mean number of individuals in home	3.6	3.5	3.7	

Note. BM = birth mother; BF = birth father; AM = adoptive mother; AF = adoptive father. Education scores were as follows: 1 (< *8th grade*), 2 (*completed 8th grade*), 3 (*completed 12th grade*), 4 (*some trade school*), 5 (*completed trade school*), 6 (*some junior college*), 7 (*completed junior college*), 8 (*some college*), 9 (*completed college*), 10 (*some graduate/professional school*), and 11 (*completed graduate/professional school*).

[a]Includes Asian, Native American/Pacific Islander, American Indian/Alaskan Native, and unknown.