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ORIGINAL RESEARCH

What Can an Adoption Study Tell Us About the Effect of Prenatal Environment on a Trait?

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Abstract Adoption studies provide possibilities for estimating the extent to which prenatal environmental events account for individual differences on a trait. Correlations with birth mothers but not adoptive mothers suggest the presence of genetic or prenatal environmental effects; higher correlations with birth mothers than with birth fathers suggest the presence of the latter. Changes over time may also be relevant. The concepts involved are illustrated with parent–child IQ correlations from the Texas and Colorado Adoption Projects.

Keywords Prenatal environment · Adoption · Birth parents · Adoptive parents · IQ

Introduction

There are many useful approaches to assessing the effects of prenatal environment on the development of traits. A number are discussed elsewhere in this issue. I will suggest that an adoption study provides one possible way of estimating the overall magnitude of prenatal environmental effects on a given trait in a human population.

Adoption studies have long been used to assess the effects of genes on psychological traits, dating from the studies on IQ of Burks (1928) and Leahy (1935). However, little or no attention has been paid to the value of adoption studies in assessing prenatal effects. There have, of course, been many studies of various sorts involving adoptions. One review (van Ijzendoorn et al. 2005) included 62 adoption studies dealing with IQ or scholastic performance. Many of these studies were focused on mean differences: e.g., is being adopted of benefit or harm to children? My concern here will be on individual variation: to what extent are individual differences in a trait due to differences in prenatal environments?

I will outline a general conceptual approach, with illustration from the IQ data of the Texas and Colorado Adoption Projects (Horn and Loehlin 2010; Plomin and DeFries 1985; Rhea et al. 2013). I should emphasize that I am using these data to illustrate a strategy, rather than to provide a compelling quantitative analysis. Data fully satisfactory for the latter do not exist, so far as I am aware. However, agreement in general tendency between two sets of adoption data obtained by different investigators under different circumstances provides some assurance that the approach is a reasonable one.

To return to the basic ideas. First, and perhaps most important, a study of children adopted at birth permits an empirical distinction between the prenatal environmental effects of a mother on her child and a mother's postnatal environmental effects, because different women provide these environments. The birth mother provides the prenatal effects, the adoptive mother provides postnatal ones. The birth mother's prenatal environmental contribution is combined with a genetic one. The mother adopting an unrelated child at birth provides only a postnatal environmental contribution. Therefore, if adoptive mothers resemble their adopted children in some trait, say IQ, but birth mothers do not, we can rule out a direct contribution of prenatal environments to individual differences on this trait in this population (and of genes as well), and attribute the resemblance to postnatal environment—whether this takes the form of explicit encouragement of the child's

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intellectual activities, imitation of the parent by the child, better neighborhoods and schools provided by better educated parents, more books in the home, or other mechanisms.

On the other hand, if the child's IQ correlates with the birth mother's IQ but not with the adoptive mother's, we suspect the influence of either the genes or the prenatal environment on the trait. How can we distinguish between these? If we have the birth father's IQs, and the effects are primarily due to the genes, we would expect about equal correlations between the birth father's and birth mother's IQs and that of the child. If correlations are present with birth mothers and not with birth fathers, we can suspect that the higher-IQ birth mother has provided a more favorable prenatal environment for her child, perhaps in the form of better prenatal medical care, a healthier diet, less smoking and drinking, less exposure to stress, or the like (or that the lower-IQ mother has provided a less favorable one).

In addition, if an adoption study involves repeated follow-up of the child, and we are dealing with a trait for which it is reasonable to hypothesize a decreasing influence of the prenatal environment over time, a declining correlation with the birth mother would be suggestive of prenatal environmental effects, whereas an increasing correlation as the child approaches the age at which the birth mother was tested would suggest genetic ones.

In practice, adoption studies often have limitations. Information on birth fathers may be limited or absent; indeed there may sometimes be uncertainty as to who the father is. Selective placement may be present: some adoption agencies may try to match the child to the adoptive home, and this may confound genetic and environmental effects. Or prenatal or postnatal environmental effects may be present and important, but not lead to parent-offspring similarity: an infection or accident unrelated to a pregnant mother's IQ may affect that of her child; or children growing up may rebel against, not conform to, parents. Such limitations should be taken into account in interpreting evidence from an adoption study regarding prenatal effects. It is always well to compare information gathered by one method with information gathered in other ways with different biases.

Finally, the methods outlined provide only overall summaries of prenatal effects. Such overall estimates may, however, be valuable in deciding where to concentrate further investigative efforts, or they may influence policy decisions. One might also include in an adoption study direct measurement of relevant prenatal variables. This has the potential for yielding immediate insight into the processes underlying an overall effect.

The Texas and Colorado Adoption Projects

I begin by describing briefly the two adoption studies that I use to illustrate how one might use adoption data to assess prenatal environmental effects. My description of the two studies, the Texas and Colorado Adoption Projects, will necessarily be brief; many more details may be found in several books reporting them (Horn and Loehlin 2010; Plomin and DeFries 1985; Plomin et al.1988; DeFries et al. 1994; Petrill et al. 2003)—or in primary sources cited in these.

The Texas Adoption Project

The Texas Adoption Project (TAP) began in the early 1970s in the Psychology Department at the University of Texas. Three hundred families who had adopted children through the Methodist Mission Home in San Antonio agreed to cooperate in the research. The adopted children, then at ages 3 through 19, were given age-appropriate IQ and personality tests, as were the adoptive parents and any available biological children of the adoptive parents or other adopted children in the families. IQ and personality test results for the birth mothers were available from the agency files, as was information about the birth fathers' occupation and education (when known), from which rough estimates of IQ could be made.

Several follow-ups of the adopted and biological children were undertaken. One was after a 10-year interval, when most were late adolescents or young adults, in roughly the same age bracket as the birth mothers were when they were tested by the adoption agency. The children were again given ability and personality tests, including the same tests that the birth mothers had taken. Some years after this, the parents in about half the adoptive families were interviewed with a focus on their children's lives. Finally, in the early 2000s, a brief mail questionnaire was sent out to all the children that could be located, then mostly in their 30s and 40s, inquiring about life outcomes, such as education, marriage, and employment history, and current personality and adjustment. Parents and (with mutual consent) siblings also filled out this questionnaire to describe the designated individual's life outcomes.

The Colorado Adoption Project

The Colorado Adoption Project (CAP) began in the mid-1970s at the Institute for Behavioral Genetics at the University of Colorado. Initially, it involved 182 infant adoptions made via two church-related adoption agencies. Birth mothers and a number of birth fathers, adoptive mothers and fathers, and a matched group of parents in ordinary biological families were given a 3-hour battery of ability and personality tests. Subsequent recruitment brought the number of adoptive families up to 245.

Ability and temperament of the infants were assessed at ages 1 and 2 years, and a dozen further follow-ups made by telephone, laboratory sessions, or home visits at ages 3 through 15, with a major follow-up at age 16. As time went on, siblings in both the adoptive and control families were added to the design. One important feature of the CAP was extensive assessment of the child's home environment at various ages. Periodic assessments of many of the CAP participants have continued past age 16, and a number of studies are ongoing.

How important is the prenatal environment? IQ as an example

In addressing "how important" questions we must be clear at the outset that we are asking "how important in accounting for individual differences," not "how important for development as such." Obviously, prenatal environment is absolutely essential for the development of human cognitive ability. No adequate prenatal environment, no IQ, end of story. Rather we are asking: Of the great variation in cognitive ability in the people we see around us, what proportion is due to their having had relatively favorable or unfavorable prenatal maternal environments, as distinct from their having relatively favorable or unfavorable genes or having had relatively favorable or unfavorable postnatal environments? In the ordinary world, these three factors tend to be correlated, so it is hard to tell, except in extreme cases, what their relative contributions might be. The result of this state of affairs has been a long and persistent wrangling among proponents of different views. The evidence from adoption studies will probably not end such arguments, but it may help. In particular, I will be concerned in this article with the evidence concerning prenatal environmental effects on a socially important, relatively well-measured variable, general intelligence, as assessed by typical IQ tests. I will not be asking "Can the prenatal environment affect IQ?" Of course it can. Rather, I will be asking "What can an adoption study tell us about the extent to which variation in IQs in the population is due to variation in prenatal environments?"

Table 1 provides relevant correlations from the two studies. The upper part of the table provides them for the TAP, the lower part for the CAP. As noted previously, there were differences in detail between the studies. The Colorado adopted children were tested at fixed ages of 7 and 16, the Texas adopted children at a range of ages centered on 8 and 17. The "biological families" in the Texas study were the adoptive parents and their own biological children. In the Colorado study they were a separate comparison group of ordinary biological families. In the Texas study the IQs of the birth fathers of the adopted children were estimated from educational and occupational data (the procedure is described in Horn and Loehlin 2010, pp. 47–49); the birth mothers' IQs were based on a nonverbal IQ test, the Revised Beta. In the Colorado study the IQs of the birth parents of the adopted children were obtained as the first principal component of performance on a battery of cognitive tests. In both studies, the birth parents' IQs were obtained close to or even preceding the child's birth, and the adoptive parents' IQs concurrently with the younger of the two ages of testing. In both studies, the adoptive parents and children received standard IQ tests, although different versions of the tests were used for the younger children, and testing conditions differed in various ways between the two studies. Nevertheless, all the measures to be discussed presumably assess general cognitive competence, so the correlations from the two studies should correspond sufficiently for illustrative purposes.

Table 1 Correlations of biological and adoptive parents' IQs with children's IQs at two ages in Texas and Colorado Adoption Projects

Parent	Child at younger age	Child at older age
Texas adoptees		
Mother, adoptive	.192 (.047/448)	.041 (.062/261)
Father, adoptive	.178 (.047/455)	.103 (.052/369)
Mother, biological	.304 (.054/346)	.349 (.069/213)
Father, biological	.222 (.067/226)	.326 (.088/128)
Texas biological families		
Mother	.252 (.080/157)	.137 (.096/108)
Father	.419 (.079/159)	.289 (.096/109)
Colorado adoptees		
Mother, adoptive	.021 (.073/186)	-.036 (.072/194)
Father, adoptive	.122 (.075/180)	.056 (.074/184)
Mother, biological	.280 (.072/195)	.266 (.069/210)
Father, biological	.066 (.156/41)	.213 (.154/42)
Colorado biological families		
Mother	.227 (.069/210)	.274 (.068/216)
Father	.202 (.070/202)	.316 (.069/211)

Standard errors/*N*s in parentheses. Younger age = 7 years in Colorado, average of 8 years in Texas. Older age = 16 years in Colorado, average of 17 years in Texas. Based on various IQ tests, except for Colorado adoptees' biological parents, where first principal component of cognitive test battery used, and Texas adoptees' biological fathers, where IQs estimated

Approximate standard errors of the individual correlations are provided in the table. These are obtained by the formula $1/\sqrt{N}$, and are thus appropriate for fairly modest correlations, such as these are, based on not-too-tiny samples (McNemar 1969, p. 155). As is evident, not all the interesting differences would be judged individually to be statistically significant, but we will chiefly rely on overall tendencies and their replication across the two studies.

The first comparison of interest is the correlations between the adopted children and their birth and adoptive mothers. A higher correlation with the adoptive mother would suggest postnatal environmental effects, a higher correlation with the birth mother would suggest prenatal or genetic ones. The results of this comparison are clear. The correlations with the adoptive mother—.192, .041, .021, −.036—are appreciably smaller than those with the birth mother, which are .304, .349, .280, .266, respectively. Insofar as a child's IQ is predictable at all from a mother's IQ in this population, genetic or prenatal influences appear to matter more than postnatal ones. And which—genetic or prenatal? Here the critical comparison is between the adopted child and the two birth parents. The birth mother provides the prenatal environment; both parents contribute equally to the child's genes. Here, because the birth fathers are restricted to cases involving reasonably clear paternity (and in the Colorado study, to a minority who were available and willing to be tested), the correlations for birth fathers are based on considerably smaller samples than those for birth mothers. On the whole, however, the correlations with birth fathers—.222, .326, .066, and .213—are appreciable, suggesting a contribution of the genes to individual differences in IQ, although the correlations are lower than the birth mothers' .304, .349, .280, and .266, suggesting a contribution of prenatal environment as well. The correlation of children with their adoptive fathers—.178, .103, .122, .056—tend to be lower than with their biological fathers—.222, .326, .066, .213—although the distinction is not as clear as with the mothers, consistent with both genes and prenatal environments being involved in the latter.

The correlations are also consistent with some modest effects of postnatal environment. Of the 8 relevant correlations with the adoptive parents, seven are positive, although the average magnitude of the correlations is only about .08, and thus of little predictive value. Moreover, in Texas selective placement may have contributed something to this correlation, although this was not an issue in the Colorado study, where selective placement appears to have been minimal.

What of trends in parent–child correlation between the younger and older ages of child testing? The differences are not great, but the child's correlation with the adoptive parents decreases in all four instances. Apparently, at least after middle childhood, longer exposure to the parents does not increase the correlation of the child's IQ with theirs. With the birth parents, the differences, such as they are, tend to be in the opposite direction. In three of four cases, the child has a higher IQ correlation with the birth parent at the later age. This is consistent with the effects of genes, which would be expected to lead to greater similarity as the child gets closer in age to the parent's age at testing. It would be a little unusual for this to be the case for prenatal environmental effects as their causal presence becomes more remote, although one can certainly imagine exceptions, such as traits related to puberty, where the effect of a prenatal event might not manifest itself at all until a dozen years later.

Limitations

I remind the reader that the data presented here are intended to illustrate an approach, not to provide final authoritative answers. In a few cases the samples are small, and all are selected in various ways. I also remind the reader that the results refer to the sources of individual differences in the population, not to the processes of development as such, for which genes and prenatal and postnatal environments are all absolutely essential.

One potential vulnerability of the present design is that it involves inferring prenatal influences from higher correlations of children with birth mothers than birth fathers. In the present studies there are some measurement issues—fathers' IQs were assessed differently than mothers' in the Texas study, and in both studies there could have been differential selection between the two groups. Also, there might be traits for which one would postulate differences in genetic transmission (such as X-linkage) that would be different for mothers and fathers—however, this is unlikely to be an issue for IQ, which appears to be massively polygenic (Plomin and Deary 2015).

Another possible concern is with assortative mating. If this occurs for a given trait—and IQ is one where it is likely—the distinctions drawn above may be a little less sharp. If higher-IQ mothers select higher-IQ partners as well as providing more favorable maternal environments, a birth father's correlation with his child might involve prenatal maternal effects to some degree. But because the product of two correlations is involved, this will not introduce a substantial bias unless both correlations are high. For example, in the Texas data the two are .29 and .15 (Horn and Loehlin 2010, p. 49), with a product of about .04—i.e., a quite small bias. The direction of this bias will be towards underestimating prenatal environmental effects and overestimating genetic ones, as it will decrease the difference between the correlations of birth mothers and birth fathers with the child.

Conclusion

Although one might argue about the details, these adoption study data suggest that the differences in IQ among these children probably reflect, in order of importance, differences in their genes, differences in their prenatal environments, and (to a modest degree) differences in their postnatal environments.

These particular data probably do not justify elaborate model-fitting: different correlations are based in part on different families and different measures, and some involve rather small samples. However, in principle one could use adoption data in a structural equation model following the logic of the present paper, and make quantitative estimates of the extent to which the genes and pre- and postnatal environments contribute to variation on a given trait.

Even at the present stage, however, these data illustrate the potential for an adoption study to establish, at least roughly, the relative contributions of genetic differences, prenatal environmental differences, and postnatal environmental differences to the observed individual differences on a trait.

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Conflict of Interest John C. Loehlin have no conflict of interest.

Human and Animal Rights and Informed Consent No data were gathered directly for this paper. The original studies were reviewed by the relevant institutional ethics committees, and the participants provided informed consent.

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