The Relationship between IQ Phenotypic Variance and IQ Heritability as a Function of Environment

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Majors: Biology & Psychology

Class: 2008

Category: Natural & Applied Sciences

Course: Bio 232 Genetic Diversity

Summary

This paper examines recent research suggesting that the relationship between heritability of IQ and environmental influences on IQ may be more complex than previously supposed. Specifically, phenotypic variance of IQ may be increasingly influenced by environmental conditions as environmental quality decreases, such that the phenotypic variance of IQ of individuals who experience high quality environments during development are strongly influenced by genetics and the phenotypic variance of individuals who experience low quality environments during development are strongly influenced by the environment.

Societal implications and future directions for research are supplied at the end of the paper. Randomized control trials aimed at determining the effectiveness of early childhood education programs for diverse groups of individuals will be important in determining how environmental interventions aimed at increasing cognitive ability can be of most value. Longitudinal research will also become increasingly important in this area of study to clarify age effects on IQ and determine the ultimate effectiveness of environmental interventions.

Introduction

In 1916, Wilhelm Stern developed IQ as a measure of the "mental age of a child divided by his or her chronological age multiplied by 100" utilizing the research of Alfred Binet on child development and age appropriate behavior and cognitive ability (Otto 2001). Since that time, many different IQ tests have been devised, the Wechsler Adult Intelligence Scale and Wechsler Intelligence Scale for Children being the most widely used today (Toga and Thompson 2005).

IQ measures typically test four cognitive domains, including verbal comprehension, perceptual organization, processing speed and working memory (Deary et al. 2006). An average correlation of 0.76 exists between the four domains, such that an individual who scores high on one domain tends to score high on the rest. The large correlation between cognitive domains provides support for the existence of a single general intelligence trait, *g*, that underlies specific abilities. Researchers obtain an estimate of *g* from IQ measures by taking the average of the scores obtained on each of the four domains. The IQ tests are devised such that the median score of each domain is one hundred (Deary et al. 2006).

Modern research has not been able to identify a single gene corresponding to *g* or IQ, and therefore both intelligence and IQ are thought to be complex traits influenced by many genes and to some extent the environment (Gray and Thompson 2004). Conversely, research has determined that intelligence and IQ are strongly associated with academic achievement, career success and longevity in human populations generating a wealth of

scientific investigations examining the genetic and environmental contributions to differences in cognitive ability (Deary et al. 2006). Decades of research have produced conflicting findings and continual debate about the effectiveness of interventions aimed at improving environmental conditions to ultimately increase cognitive ability, such as early childhood education programs.

Several recent studies have suggested that determining the value of environmental interventions may not be as simple as achieving consensus on a single value representing IQ heritability. Instead, evidence suggests that heritability of IQ may depend on the environmental conditions one is subjected to. Specifically, genetics may be more influential on the IQ of individuals experiencing high quality environments, whereas genetics may be less influential and environment more influential on the IQ of individuals experiencing impoverished environments (Turkheimer et al. 2003).

This paper first reviews the construct of heritability, the methods by which it is measured in scientific research, the wide range of reported IQ heritability values found in the literature and the genes that may account for the observed heritability. Then several studies are discussed which suggest that the relationship between the phenotypic variance of IQ and heritability of IQ may depend on specific environmental circumstances. Finally, the implications of this new model are addressed, as well as important next steps for researchers in the field.

Heritability

IQ heritability, or the extent to which genetic differences account for phenotypic differences in IQ, is an extremely relevant and important area of research. One's IQ is strongly associated with life outcomes. For example, IQ scores are "about the single best predictors of job success" (Deary et al. 2006). Moreover, conclusive findings relating to IQ heritability will more definitively answer the lingering questions surrounding the societal benefits and cost effectiveness of environmental interventions aimed at increasing cognitive ability and will inform policies regarding these interventions (Turkheimer et al. 2003).

Human heritability estimates of IQ are generally determined by genetic similarities between relatives. For example, researchers often compare the correlations of traits between monozygotic twins, who share 100% of their genes, and dizygotic twins, who share 50% of their genetic material to obtain an estimate of heritability. Other valuable comparisons commonly used in heritability studies include half-siblings, adopted individuals and their biological and adopted relatives and monozygotic twins raised apart from one another (Griffiths et al. 2005). Meta-analyses examining the heritability of IQ have consistently found genetic differences to account for about 50% of IQ variance, but in single studies the reported values for IQ heritability range from 0.2 to 0.8 (Otto 2001; Deary et al. 2006).

In response to the large genetic component suggested by some studies, many researchers are currently attempting to locate the particular genes that account for the

demonstrated heritability. Genome wide linkage studies have identified 2q and 6p as chromosome regions that could be associated with *g* and IQ. Genes associated with cognitive disabilities are also of particular interest to researchers, because the genes could also be associated with normative development (Deary et al. 2006). Currently, genes for brain volume are being explored as well, because the trait is known to be closely linked with intelligence (Hulshoff Pol et al. 2006). Specific genes that have been associated with IQ thus far include the genes for klotho, the cholinergic muscarinic 2 receptor, cathepsin D and succinate-semialdehyde dehydrogenase. Yet, each of these genes has accounted for only a small part of the total heritability of IQ (Deary et al. 2006).

The Environment

Although the genetic influence on IQ has been well demonstrated and even linked to particular genes and regions of chromosomes, researchers have not currently reached a consensus as to the specific heritability of IQ or reconciled the previously mentioned wide range of heritability values reported in the literature. The importance of environmental influences on phenotypic variance of IQ was first convincingly demonstrated in 1987 by the "Flynn effect," the phenomenon of increasing average IQ scores in a population over time such that measures of IQ must be re-adjusted to ensure the median score remains at 100 (Toga and Thompson 2005). Between 1952 and 1982 the average IQ of eighteen year old men from the Netherlands increased by over twenty points (Flynn 1987). Similar rates have since been found in replication studies utilizing

data from diverse populations. This rate of increase is much too great to be explained by genetic variation and can therefore only be attributed to improved environmental conditions over the thirty year span, including "improved schooling and technology, better access to education, improved nutrition and reduction in some environmental toxins" (Toga and Thompson 2005).

Similarly, the influence of environmental quality on the phenotypic variance of IQ has been explored in the context of ethnicity and IQ. In a review of literature, Nisbett (2005) demonstrates that over the past forty years, the IQ gap between Caucasians and economically disadvantaged minority groups, particularly African-Americans, has decreased considerably. To date, improved environmental conditions, including increased access to education, healthcare and technology are the only empirically supported explanations for the narrowing gap. Furthermore, transracial adoption studies suggest that environmental factors can have a drastic influence on the IQ of individuals from disadvantaged backgrounds. A multitude of studies have demonstrated that when adopted into families of European descent, children of ethnicities traditionally associated with lower socioeconomic status and lower IQ scores achieve IQ scores typical of those from more privileged backgrounds (Nisbett 2005).

The New Model: IQ's Phenotypic Variance and Heritability in the Context of Environmental Quality

Several recent studies have been published directly examining the possibility that environmental quality alters the heritability of IQ (Turkheimer et al. 2003; van Ijzendoorn et al. 2005). The new model presented by these studies could explain the large range of heritability values found in relevant literature and provide definitive support for the value and effectiveness of environmental interventions aimed at increasing cognitive ability.

Turkheimer et al. (2003) specifically tested the hypothesis that IQ heritability depends on the quality of the environment by utilizing socioeconomic status to operationalize environmental quality. The researchers studied 319 pairs of monozygotic and dizygotic twins recruited from urban hospitals in the United States. A large proportion of the families recruited for the study were of low socioeconomic status. Twenty-five percent of the families reported incomes below the poverty level. Through statistical analyses comparing the monozygotic and dizygotic twins, the researchers found support for their hypothesis. Among twins of low socioeconomic status heritability accounted for 10% of IQ's phenotypic variance, whereas shared environment accounted for 58% of the phenotypic variance. On the other hand, among twins from families of higher socioeconomic status, heritability accounted for 72% of the phenotypic variance of IQ and shared environment accounted for only 15% (Turkheimer et al. 2003).

More recently, van Ijzendoorn et al. (2005) demonstrated further support for Turkheimer et al.'s (2003) hypothesis in the context of adoption. Most often adopted children come from economically disadvantaged biological families and are adopted into families of higher socioeconomic status where the child is provided with a safer and more enriching environment for development. Van Ijzendoorn et al.'s (2005) meta-analysis of

sixty-two adoption studies found that adopted children tend to have IQ scores that are significantly higher than those of their non-adopted biological siblings and non-adopted institutionalized peers. Strong evidence suggests the IQ differences originate from the dramatic environment change, from impoverished to enriched, experienced by the adopted child. Moreover, adopted children are found to develop IQs which are not significantly different from their adoptive siblings and adoptive environmental peers (Ijzendoorn et al. 2005).

The findings in this body of research make intuitive sense when one is reminded that "heritability does not imply inevitability" (Toga and Thompson 2005). Instead, heritability provides us with the proportion of phenotypic variance in a trait due to genetic variation within the context of a clearly specified environment. An analogy can be drawn between the heritability of intelligence and the heritability of height. Height is a largely heritable trait when nutrition does not limit one's growth. Perhaps, in the same way, intelligence is a largely heritable trait when environmental toxins, cognitive stimulation and nutrition do not limit one's cognitive development (Toga and Thompson 2005).

Implications and Future Directions

The implications for these findings are immense. Most research conducted on the heritability of IQ has assumed that one heritability value fits all. If evidence continues to accumulate supporting the idea that genes play a large role in determining IQ in high

quality environments but not low quality environments, many studies examining the heritability of IQ will be invalidated. This is especially true of studies that have grouped together participants without accounting for the varying environmental contexts experienced by participants as well as studies that did not include individuals from disadvantaged backgrounds.

Societal implications arising from this research on the heritability and environmental variance affecting the phenotypic variance of IQ are also great. The "Flynn effect," in particular, suggests that environmental interventions aimed at increasing IQ scores are effective and important for society to invest in. Thus far, the average IQ of various populations has been increasing at rates unexplainable by genetics alone, which can be fully attributed to environmental changes over the past thirty years (Toga and Thompson 2005).

In light of these findings, early childhood education programs, regain some credibility, as their ability to produce lasting effects on achievement and cognitive ability has been widely questioned. This is especially true of programs serving youth from disadvantaged backgrounds that, according to the new model, can benefit greatly from a more enriched environment. Studies focusing on children from families of low socioeconomic status have produced data supporting these ideas, as they suggests that intensive early childhood education programs can create lasting effect on both IQ and achievement scores in these populations (Gorey 2001).

The findings also imply many important and interesting directions for future research. One study design that could yield relevant information on the phenotypic

variance of IQ as well as public policy and education would be the random assignment of children from impoverished environments and children from enriched environments to an intensive early childhood education and control groups. The control groups should reflect "treatment-as-usual." In other words, children in the control groups would be afforded the educational opportunities and environmental experiences they would receive from their parents without participating in a study. If significant differences were found between the IQ scores of children in the intensive early childhood education program and control groups from low quality environments, but not found or are demonstrated to be much smaller between the two groups of children from higher quality environments this would provide great support for the new model. Findings like these could also address the issue of how to maximize the cost-effectiveness of early childhood education programs.

Similarly, it will become increasingly important to identify the conditions that make one environmental intervention more effective than others. Several studies have found particular childhood education programs to be ineffective at producing long-term results on either cognitive ability or academic achievement among the studied population (Adams 1989; Jensen 1993). To ensure interventions are as effective as possible, researchers need to directly compare the long-term results produced by various interventions side by side using a randomized control trial design.

Longitudinal studies will also be particularly important in future research. Some studies have suggested that the phenotypic variance of IQ is influenced decreasingly by shared environment influences and increasingly by genetic heritability from early childhood to adolescence (Deary et al. 2006). It is yet to be determined whether these

findings are true of both individuals from high and low quality environments. Additionally, intensive early childhood education programs have proven to have lasting effects up to the age of fifteen, but the effects of the intervention programs have not yet been examined in scientific research past this age (Nisbett 2005). Longitudinal studies could address both of these unanswered questions.

Thus far, environmental quality has been operationalized in this body of research using socioeconomic status alone. Future inquires should attempt to operationalize environmental quality using additional measures to create a fuller picture of environmental conditions experienced by participants and possibly strengthen findings. A measure that assesses individual's neighborhoods for crime, healthcare accessibility, the availability of nutritious foods and crowding could serve as an interesting addition.

Finally, gene-environment interactions are often neglected in studies, because of the difficulty in identifying and quantifying their influence. It is likely that when dealing with complex traits, such as IQ, gene-environment interactions play a significant role in the phenotypic variance. For example, individuals of high cognitive ability may seek out mentally challenging activities that ultimately increase their cognitive ability (Toga and Thompson 2005). As the relationship between heritability and environmental conditions becomes clearer, it will become increasingly important to devise ways to identify these gene-environment interactions and their consequences.

In closing, the interplay between environment and heritability as they relate to IQ and intelligence is now being realized as increasingly complex. When considering the relationship between phenotypic variance of IQ and heritability in the context of different

environments and the consequences of these relationships, one must be aware of the complexities and keep in mind all that we still do not know. S.P. Otto (2001) sums up this idea by saying:

> Even with an estimate of heritability, we know nothing about the reasons for the IQ of any given individual. Furthermore, heritability depends entirely on the set of environments in which it is measured. If one changes the environment, heritability may change in unpredictable ways, both because the phenotypic variance depends on the variance in environmental effects and because genotypic effects may depend on the environment.

References

Adams, M. J., 1989. Thinking skills curricula: Their promise and progress. Educational Psychologist 24: 25-77.

Deary, I. J., F. M. Spinath, and T. C. Bates, 2006. Genetics of intelligence. European Journal of Human Genetics 14: 690-700.

Flynn, J. R., 1987. Massive IQ gains in 14 nations: What IQ tests really measure. Psychological Bulletin 101: 171-191.

Gorey, K. M., 2001. Early childhood education: A meta-analytical affirmation of the short- and long-term benefits of educational opportunity. School Psychology Quarterly 16: 9-30.

Gray, J. R., and P. M. Thompson, 2004. Neurobiology of intelligence: Science and ethics. Nature Reviews 5: 471-482.

Griffiths, A. J. F., S. R. Wessler, R. C. Lewontin, W. M. Gelbart, D. T. Suzuki, and J. H. Miller, 2005. Introduction to Genetic Analysis 8e. W. H. Freeman and Company, New York.

Hulshoff Pol, H. E., H. G. Schnack, D. Posthuma, R. C. W. Mandl, W. F. Baare, C. van Oel, N. E. van Haren, D. L. Collins, A. C. Evans, K. Amunts, U. Burgel, K. Zilles, E. de Geus, D. I. Boomsma, and R. S. Kahn, 2006. Genetic contributions to human brain morphology and intelligence. The Journal of Neuroscience 26: 10235-10242.

Jensen, A. R., 1993. Psychometric g and achievement. Policy Perspectives on Educational Testing, 117-127. Boston: Kluwer Academic Publishers.

Nisbett, R. E., 2005. Heredity, environment, and race differences in IQ. Psychology, Public Policy, and Law 11: 302-310.

Otto, S.P., 2001. Intelligence, Genetics of: Heritability and Causation. International Encyclopedia of the Social and Behavioral Sciences 11: 7651-7658.

Toga, A. W., and P. M. Thompson, 2005. Genetics of brain structure and intelligence. Annual Review of Neuroscience 28:1-23.

Turkheimer, E., A. Haley, M. Waldron, B. D'Onofrio, and I. I. Gottesman, 2003. Socioeconomic status modifies heritability of IQ in young children. Psychological Science 14: 623-628.

Van Ijzendoorn, M. H., F. Juffer, and C. W. Klein Poelhuis, 2005. Adoption and cognitive development: A meta-analytic comparison of adopted and nonadopted children's IQ and school performance. Psychological Bulletin 131: 301-316.