Title

Apart from genetics: What makes monozygotic twins similar?

Journal

Journal of Mind and Behavior, 22(2)

Author

Mandler, George

Publication Date

2001

Peer reviewed

1

Apart from Genetics: What Makes Monozygotic Twins Similar?

George Mandler

University of California, San Diego and University College London

1

Running head: Monozygotic twins

Originally published in *Journal of Mind and Behavior,* Spring 2001*,* Volume 22, Number 2, Pages 147-160.

Apart from genetics: What makes monozygotic twins similar?

Abstract

Identical (monozygotic) twins have attracted special attention for the study of behavior genetics. Some of the assumptions and results of these studies are reviewed with special attention given to the natural experiment of identical twins adopted by different families. However, the correlation for any behavior between the adopted twins of a monozygotic pair is affected by their common prenatal environment as well as by the pervasive similarity of the two adoptive environments. The genetic contribution to complex social phenomena, but also to physical characteristics such as height, is usually overestimated. Both for adopted and unadopted twins differential effects of cultural, family, and prenatal environments, and the correlated experiences of twins and their physical appearance affect their development. Taxonomies and samples of environments need be examined in order to be able to estimate the genetic contributions to behavioral traits.

In recent years the wide ranging speculations of early sociobiologists (Barash, 1977) have given place to dedicated research on the genetics of human characteristics. Given the theoretical and practical importance of these results, it is crucial that any possible methodological errors or artifacts be avoided. I discuss some difficulties of twin research and adoptive twin research in particular. I start with a discussion of the similarity of adoptive environments short of random placement and then explore the extent to which unadopted twins share or do not share environments or grow up in equal environments. I then move to some general characteristics of MZ twins and conclude with suggestions for the sampling of differential environments.

With respect to research with adopted twins, the main approach I wish to examine is described by Plomin, DeFries and McClearn as the situation "in which identical twins are adopted separately at birth and reared apart in uncorrelated environments. The resemblance of these pairs, expressed as a correlation, can be attributed to heredity" (1990, p. 346). I note first that identical twins are rarely adopted "at birth" -- usually some time and even years after birth. The main issue I discuss is the problem of correlated and uncorrelated environments as well as factors other than genetics that may make twins behave in a similar fashion. Previous critiques of adoption studies (for example, Kamin, 1974; Schiff and Lewontin, 1986; see also Lewontin, Rose, and Kamin, 1984) have focussed on genetic studies of IQ. More recently the general problem of monozygotic twin studies (though usually in the context of IQ studies) have received critical attention (cf. Beckwith, 1999; Joseph, 1998; Machin, 1996).

The Basic Problem

I illustrate the basic problem of adoption studies with a simple example: "[T]he correlation for reared-apart identical twins for height is about 0.90. This implies that about 90 percent of the variation in height is shared by reared-apart identical twins. This resemblance -- unlike the resemblance for identical twins reared together -- cannot be due to shared environment, because the twins were adopted apart and lived in different families that are uncorrelated in terms of height" (Plomin et al., 1990, p. 346). The difficulty with this statement is that different families may be uncorrelated in terms of height, but they may or may not be correlated in terms of nutrition. Since it is known that nutritional deprivation affects physical height (Ruel, Rivera, Habicht, and Martorell, 1995), the obtained correlation might well have been an underestimate if the two environments were *negatively* correlated in nutrition, with one of the twin pairs raised at less than maintenance diet, and the other raised in an average nutritional environment. However, the twins were presumably not placed in families that were extremely different from each other, their environments were correlated in terms of nutrition (and its effect on height), and the correlation value is probably an over-estimate. To illustrate in detail: consider sets of twins designated as A and B; then there are $A_1 \ldots A_j$ and $B_1 \ldots B_j$ individuals for *j* set of twins. Assume that the twins are placed in completely identical adoptive environments, equal in nutrition etc. Then the only variation between pairs of twins will be due to prenatal influences, and in their absence the correlation for height of the *j* sets of twins will be 1.00. Now assume that for 25% of the twins the A twin is placed in average environments and the B twin is placed in a nutritionally impoverished family. For these 25% of the pairs the correlation for height will obviously not be at unity, since the twin placed in the nutritionally inadequate family will be shorter than the other twin by some unspecified value. And the overall correlation for all twin pairs will also fall below 1.00. More generally, the more similar the environments nutritionally the higher the correlation will be. If the placement of the twins were random in the

society at large with exposure to the large variations in nutrition ranging from very poor to financially secure families the correlation would necessarily be lower than if the twins were all placed in nutritionally similar environments.

Before addressing the problem of the correlated environments of adopted twins directly, I summarize some critical analyses of available twin data. Taylor (1980) and Farber (1981) have reanalyzed the available data on monozygotic twins. Taylor investigated data from three studies (Juel-Nielsen, 1980; Newman, Freeman, and Holzinger, 1937; Shields, 1962)[1] on twins reared apart on the basis of their similarity on four environmental variables: age of separation, reunion in childhood, rearing by a relative, and similarity in social environment. He concluded that the similarity of the twins could be ascribed to similarities on three environmental variables, i.e., when twins were reunited in childhood, if they were reared by relatives, and if twins had more similar social environments. Bouchard (1983) has presented a reanalysis of these data by using alternative intelligence test scores for the Juel-Nielsen and Newman et al. studies. For age of separation (> or < 6 months) Bouchard did find that late separated twins had a higher mean IQ correlation (.79) than those separated early (.42). He dismisses this difference on the basis of Taylor's data which did not find such a difference (using a different intelligence test). For the three other variables where he finds either a smaller (or no) difference due to environment he dismisses the Taylor data on the basis of his own analyses.[2] Farber (1981) in a general survey of twins reared apart included extensive analyses of IQ scores. Relevant to my discussion is her reanalysis of IQ scores when degree of separation is included in the analyses. Heritabilities of males and females drop from .74 to .45 and from .76 to .48 (p = .05 and .01) respectively when separation is taken into account (pp. 195-198). Thus, amount of common environment (nonseparated periods) significantly affects the correlation of MZ twin pairs. In a review of Farber's book, Bouchard (1982) raises a number of issues but did not address the separation issue in detail. Rose, in another review of Farber's book, notes that the *N*s for these studies are deplorably small but that, in contrast to personality studies of twins, analyses of shared environmental factors applied to IQ "demand, that a significant portion of the variance be attributed to common environmental effects" (1982, p. 959). A conservative conclusion to be drawn from these studies is that there is some evidence for common environmental factors accounting for the similarity of adopted MZ twins. What factors may be responsible for some of those commonalities.[3]

The Adoptive Environments

When identical (monozygotic) twins are adopted and placed with different families the two environments tend to be similar and the ranges and varieties of environments sampled will be relatively small (Kamin, 1974). The lore about adoption agencies is that they try to place twins in similar environments. In a minority of cases, if that is not possible the twins are placed in the first available families.[4] In either case they are placed in "similar" families belonging to the

---

1 The data of Cyril Burt's study were omitted because of the well known likelihood of fraudulent manipulation of those data (Tucker, 1997).

2. Bouchard does not comment on how standard IQ tests that are supposed to be robust measures of a genetic background (Wechsler-Bellevue, Stanford-Binet, Otis, Raven) can vary so widely in these analyses.

3. For general arguments on environmental influences on gene activation see Gottlieb (1998).

4. Until recently some adoptive placements were even restricted by law.

same culture. Thus, it is highly unlikely that one twin will be placed with a family living under the poverty level and the other with the family of the president of a major company. Such a placement would be more likely if twins were placed randomly, then the likelihood that one twin ends up in the upper 2% of income and the other in the lowest 2% is the same as both twins ending up in the upper (or lower) 2%. In fact, however, twins generally tend to end up in similar environments in terms of economic status. But even if adoptions were random within a particular town, region, or country, the similarity between environments would of course still be there -- two households in Great Britain are more similar than if one is in the U.S. and the other one in Siberia, North China, Corsica, or Papua New Guinea. Adoptive environments in a single country or culture will be correlated to some extent; and they will be correlated to a very large extent if the adoptive environments are sampled from similar socio-economic groups within the same culture. In any case, the two environments will not be "uncorrelated" (Plomin, 1990), and the fact that the twins are of the same age and sex creates its own correlated environment (cf. McGue and Bouchard, 1984). Even if randomization of adoptions were possible within a particular social group a researcher would need to be concerned what generalizations she wishes to make. Are the twins placed within a particular culture or even subculture? And to what population would one wish to generalize? For example, if one were devising a personality test for a particular culture then there is no need to go beyond that culture. But if one wanted to make statements valid for all populations (regardless of environment) then, of course, a large sampling base would be needed.

Shared, and Equal, Environments?

Problems of environmental sampling (and information) also apply to another paradigm of twin studies, in this case of unseparated twins. In such a design, in addition to examining similarities between identical (monozygotic) twin pairs, a control group of nonidentical but same sex (dizygotic) twins is examined. Both types of twins are unseparated, i.e., reared in the "same" environment. The argument is that in one group genetic endowment is held constant and environment is varied, while in the other both endowment and environment are allowed to vary. If the behavior of the identical twins is more alike than that of the nonidentical twins then one might conclude that genetics is more important than environment.[5] While in the adoptive twin method with twins reared apart, it is important that the environment (in the two adoptive homes) is different and preferably chosen at random, in this case it is implied that both identical and fraternal twins share the same environment.

The assumptions that the environments of MZ and DZ twins are more or less identical and particularly that twins share equal environments have been repeatedly examined (see, for example, Hettema, Neale, and Kendler, 1995; Joseph, 1998; Morris-Yates, Andrews, Howie, and Henderson, 1990). However, there is little detailed longitudinal information about the

---

5. But even that conclusion is not assured since the heritability in such a case may be below .50 in which case the larger part of the population variance would be attributable to environmental factors.

differential treatment, if any, of identical and nonidentical twins and how such differences in treatment might affect their behavior. Rather crude measures of parental recollection of how parents treated their children are not generally useful since parents tend to give an idealized picture of their own and their children's behavior. Joseph (1998) has examined the literature on the equal environment assumption and has persuasively argued that the environment shared by monozygotic twins is different from that of dizygotic twins.

The equal environment assumption states that identical twins, who look alike, are treated the same way as fraternal twins, who do not look as much alike. In fact, it is likely that physical similarity will influence the degree of similar or differential treatment. Berscheid (1996, p.5) has examined these issues and concluded that "... many morphological features ... lead to inferences about other, less easily discerned, dispositional characteristics ... (for example, intelligence, personality)" [see also Langlois et al., 2000]. I return to this issue below.

Problems very similar to those associated with adoption studies arise in attempts to estimate the effect of shared environments -- independent of genetic contributions. Studies that compare identical twins reared together with unrelated children placed in the same adoptive family are potentially more compelling. The argument is that for the unrelated subjects nature is randomly varied whereas nurture (the family) is the same for both children. But consider the inevitable selection involved and how different these contexts are from twin studies with which these outcomes are compared. Of course, to the extent that the children are of different ages or gender they do *not* share the same environment. Furthermore, families that adopt two or more children are surely not random samples of families within a culture, much less of families across cultures. We do not know what difference these selective characteristics produce in environmental variation, but they <u>are</u> selective.

When MZ and DZ twins are raised together, can they be said to share the same environment? The answer is that they do not, as an early study by von Bracken (1934) already showed. He conducted extensive interviews with the twins, the parents, and teachers of 15 monozygotic and 12 dizygotic pairs. The most important findings were that the MZ twins hardly ever separated, that DZ twins fight over desired items while MZs do not, that MZs help one another in school more than do DZs, that when one MZ twin is punished the other always shows great empathy whereas DZs tend to be indifferent, that MZs tend to have the same playmates whereas DZs do not, and that direction of interests in games and reading material tends to be the same for MZs but different for DZs. Von Bracken concluded that environment affects MZs and DZs in different fashions. A similar conclusion was reached by Smith (1965) whose comparisons of MZ and DZ twins showed that, for example, MZ twins were much more likely than DZ twins to dress alike, study together, and have the same close friends.

It has been argued (for example, Bouchard, 1997) that the similarities between MZ twins that are other than genetically determined must be shown to be trait-relevant in order to be used as a counter to the strictly genetic argument. In the first instance it is highly likely that pervasiveness of the cultural environment that the twins share plays into many if not most psychological traits. However, detailed analyses of the environments in question are rarely available for each particular twin study, and whereas some early twin studies have provided detailed environmental data, more recent studies have concentrated almost exclusively on quantitative data. Detailed information on how the twins were sampled and raised is rarely available. Behavior geneticists should spell out what environmental factors would be trait-relevant and then provide data to show that the actual shared environments are not relevant. Finally, the likelihood that IQ measures are strongly sensitive to cultural and social change (for example, Flynn, 1987; Ogbu, 1978) suggests that common cultural environments are trait-relevant not only for IQ measures but for other related characteristics as well.

To return to adoptive studies, matters improve somewhat, but still are problematic, when

we consider the most sophisticated kind of twin study: examining adopted identical and adopted fraternal twins. Whenever the data show higher correlations for the identical than for the fraternal twins, the similarity of the adoptive environments still restricts severely the population to which one can generalize. We do not know whether adoption agencies handle the placement of identical twins exactly the same way as the adoption of nonidentical twins. And at the phenotypic level, identical twins are physically similar -- they look alike -- a characteristic that affects this as well as other types of twin studies.

Specific Characteristics of MZ Twins

Physical Similarity

What are the consequences of the physical similarity of MZ twins? Consider a study of identical and nonidentical twins which concluded that genetic factors strongly influenced the etiology of divorce (McGue and Lykken, 1992). The finding was that the risk for divorce is greater for individuals whose identical co-twins have been divorced than it is for individuals whose nonidentical co-twins have been divorced. The data were obtained from a subsample of available twin cohorts. We do not know what proportion of the twin pairs actually responded to the inquiry and what the characteristics of this subsample might have been. The method is subject to obvious sampling biases: for example, what is the likelihood that people would reply to such an inquiry given that there is or is not a history of divorce in their family? Or consider the fact that identical twins look more alike than nonidentical ones and are therefore more similar in attractiveness. In our society physical attractiveness level is associated with the availability of alternative partners. The availability of alternative partners, in turn, is associated with divorce, and therefore divorce risk among identical co-twins should be greater than divorce risk among nonidentical twins.

Another example of both sampling problems and inadequate attention to phenotypic effects is found in a study by Dunne et al. (1997). The study used data from a sample of 5,080 individuals (at least half of whom were alcoholics) from an original volunteer twin sample of 12,212 (with only a 41% response) to investigate the effects of genetic factors on age of first sexual intercourse. There is no discussion what possible bias such a sample may hide or what selection procedures are introduced by subjects who may or may not wish to answer what might be viewed as a sensitive issue. More surprising is the lack of any attempt to explore environmental bases for the phenomenon. Among those that come to mind is, of course, the physical similarity of MZ twins. Since in Western society sexual union is very frequently determined by physical characteristics, one would suppose that, for example, people who are selected for such union early in life because of their attractiveness will on the average have MZ twins subject to the same selection pressure. Conversely, the socially unattractive will be selected later in life (both twins again experiencing the same selection pressures).

Environmental influences can produce a number of social and behavioral effects that may lead to erroneous conclusions about implied genetic influences.[6]

MZ twins look alike -- which means that they are also alike in attractiveness or the lack thereof. The similarity in attractiveness of MZ twins has received relatively little attention, even though there is a large literature on the effects of physical attractiveness (see Berscheid and Reis [1997] for an extensive review and detailed accounts). Whereas personality measures and mental abilities show little association with attractiveness, other aspects such as social skill and competence, sexual experience, and social interactions do covary with attractiveness (see Eagly, Ashmore, Makhijani, and Longo, 1991; Feingold, 1992; Reis et al., 1982). The most thorough investigation of attractiveness has been presented by Langlois et al. (2000), who found that attractive individuals are judged more positively than unattractive ones, are treated more positively, and exhibit more positive behaviors and traits. In addition, ratings of attractiveness show acceptable levels of agreement both within and across cultures. Given that attractiveness is an important determiner of how people are treated in our society, attractiveness will likewise be important in the treatment of MZ twins. Since MZ twins are equally attractive or unattractive, they will be treated and will behave in similar ways whether reared together or reared apart.

Prenatal Environments

Machin (1996) has concluded, that "[m]ost monozygotic twin pairs are not identical; there may be major discordance for birth weight, genetic disease, and congenital anomalies" (p. 216). A study on the heritability of schizophrenia (Davis, Phelps, and Bracha, 1995) started with the generally accepted finding that monozygotic twins are likely to be 50% concordant for schizophrenia (compared with dizygotic twins at less than 20%). Davis and his co-workers then explored the pre-natal environment of their monozygotic twins. Twins may pre-natally share one placenta (monochorionic) or may each develop in a separate placenta (dichorionic). Dichorionic twins have somewhat different environments, particularly with respect to shared fetal blood circulation. Results showed that the concordance for schizophrenia for monochorionic pairs was 60%, whereas for dichorionic pairs it was 11%. Thus, with the identical genetic make-up of twin pairs, pre-natal environment was crucial in determining the eventual development of schizophrenia (see also Spitz and Carlier, 1996). Devlin et al. also examined the effect of the common womb environment for twins. They concluded *inter alia* that the "shared maternal environment may explain the striking correlation between the IQs of twins, especially those of adult twins that were reared apart" (Devlin, Daniels, and Roeder, 1997, p. 468).

6.For example, environmental and social effects may lead one to "discover" such ludicrous sociobiological phenomena as that one of the highest genetic heritability indices is likely to be the size of one's bank account (Jones, 1991).

Sampling the Environment

One dilemma facing adoptive twin research concerns the populations to which one wishes to generalize. Little attempt is made in the literature to restrict such generalizations; the implication is usually that the findings apply to human populations at large. But as I have noted earlier, the choice of adoptive homes and the correlation between adoptive homes is crucial. In fact, if one wanted to make statements about nature and nurture, or about such important topics as aggression or intelligence, one would need to place the adoptive twins in homes randomly selected and dispersed over the inhabited world (see also Pinel, 1997, p.47). Random placement of adopted children is of course unlikely to happen.

Is there any possible solution to the problem of environmental sampling? Whereas suggestions have been made to improve environmental measures (DeFries and Plomin, 1978), little actual research has been devoted to this problem, though in some contexts initial steps toward a taxonomy of environments have been undertaken (Moos, 1996). In addition, one needs to consider the findings about the importance of non-shared environments. It appears that environmental differences between children in the same family represent a major source of environmental variance for a number of different characteristics (Plomin and Daniels, 1987). These data suggest that there are important environmental variables of which we are as yet insufficiently aware (see also Hetherington et al., 1994).

What is needed is a more careful analysis of environments. We have no taxonomy of environments at present and an understanding of the complexities of environment/genetic interactions depends on being equally precise about both factors. We need to develop more sensitive measures of the socio-cultural environment, including possibly some composite measure of the available social information similar, for example, to the now dated Hollingshead Index (Hollingshead and Redlich, 1958). Single composite measures might be preferable to simple indexes such as socio-economic status or the sampling of environmental variables one at a time (Bouchard et al., 1990). Such composite indices have the same drawbacks as single number indices of intelligence, but for purposes of comparison they may well be worth pursuing as initial steps.

The concern with adoptive procedures on studies of twins has been with us for over a quarter of a century, but little progress has been made to ameliorate the effect of these procedures. Rather, social conclusions still are drawn on the basis of at least tentative if not spurious data (cf. Beckwith, 1999). The interaction of environment and genetic endowment is at best difficult to disentangle, but its specification is important enough to employ extra diligence in its investigation. In actual studies it is even more difficult to define and specify the functional environment. If pre-natal environment interacts with genetic disposition, consider how much the personal/historical environment interacts with social dispositions. What will be needed is a multi-dimensional approach to an understanding of environments. First, we need to know which environmental factors affect specific behavior and how they do so. One would have to be sensitive to very specific nature/nurture interactions, for example, in a study of difference in male and female cognitive achievements in patriarchal vs. matriarchal cultures. We will need to consider the summing and interactive influences of such things as parental education and economic status, the individuals education and social support, the importance of crucial life-defining events, of losses, of griefs and successes, etc.[7] Second, we need to know how various environments are distributed in the human habitat (the world at large). The choice of

---

7.Howe, Davidson, and Sloboda (1998) have presented data to show how intense environmental pressures and events can account for individual differences usually ascribed to talent.

environments may be limited if one wished to make generalizations only about nature/nurture interactions in London or in France or in Western industrial countries or in preliterate societies etc. In that respect, the questions I address are not unique to behavior genetics; similar issues arise in the generalizability of opinion polling and market research, for example. To know whether one's gizmo will sell in Bangladesh it is useless to test-market it in Nigeria. Third, one would also need to determine how best to combine various environmental measures into a single useful measure of environmental efficacy. Once such groundwork has been completed one could compare the difference in the environments of adopted twins with the actual variability available in the target population. In the meantime, it is obvious that behavior genetics research needs to exercise greater care in its generalizations based on work with MZ and DZ twins.

And yet, given these problems in method and analysis one may ask how the basic twin research has survived. Among the possible answers I suggest two. First of all, I have argued that psychology is very sensitive to social situational factors in the culture in which it is embedded (Mandler, 1996). We live in an era which has in part embraced nativist and reductionist approaches in the human sciences and psychology reflects that trend. Secondly, the history of psychology has been cyclical in its commitment to some basic underlying positions. One of these cyclical trends has been the varying emphasis on nativist and environmental interpretations of human nature. In these Hegelian cycles history repeats itself to some extent but usually does so at a more sophisticated level each time. At present we have already moved away from the speculative excesses of sociobiology of a quarter century ago. It may well be that the recent increase in critical appraisals of behavior genetics heralds a new and more fruitful synthesis of the genetics/environment interaction.

References

Barash, D. P. (1977). Sociobiology and behavior. Amsterdam: Elsevier.

Beckwith, J. (1999). Simplicity and complexity: Is IQ ready for genetics? Cahiers de Psychologie Cognitive/Current Psychology of Cognition, 18, 161-169.

Berscheid, E. (1996). The "paradigm of family transcendence": Not a paradigm, questionably transcendent, but valuable nonetheless. Journal of Marriage and the Family, 58, 1-9.

Berscheid, E., and Reis, H. (1997). Attraction and close relationships. In D. T. Gilbert, S. T. Fiske, and G. Lindzey (Eds.), The handbook of social psychology (fourth edition, volume 2, pp. 193-281). New York: Oxford University Press.

Bouchard, T. J., Jr. (1982). Identical twins reared apart: Reanalysis or pseudo-analysis? Contemporary psychology, 27, 190-191.

Bouchard, T. J., Jr. (1983). Do environmental similarities explain the similarity in intelligence of identical twins reared apart? Intelligence, 7, 175-184.

Bouchard, T. J., Jr. (1997). IQ similarity in twins reared apart: Findings and responses to critics. In R. J. Sternberg and E. L. Grigorenko (Eds.), Intelligence, heredity, and environment (pp. 126-160). Cambridge, Massachusetts: Cambridge University Press.

Bouchard, T. J., Jr., Lykken, D. T., McGue, M., Siegal, N. L., and Tellegen, A. (1990). Sources of human psychological differences: The Minnesota study of twins reared apart. Science, 250, 223-228.

Davis, J. O., Phelps, J. A., and Bracha, H. S. (1995). Prenatal development of monozygotic twins and concordance for schizophrenia. Schizophrenia Bulletin, 21, 357-366.

DeFries, J. C., and Plomin, R. (1978). Behavioral genetics. Annual Review of Psychology, 29, 473-515.

Devlin, B., Daniels, M., and Roeder, K. (1997, July). The heritability of IQ. Nature, 388, 468-471.

Dunne, M. P., Martin, N. G., Statham, D. J., Slutske, W. S., Dinwiddie, S. H., Bucholz, K. K., Madden, P. A. F., and Heath, A. C. (1997). Genetic and environmental contributions to variance in age at first sexual intercourse. Psychological Science, 8, 211-216.

Eagly, A. H., Ashmore, R., Makhijani, M. G., and Longo, L. C. (1991). What is beautiful is good, but . . .: A meta-analytic review of research on the physical attractiveness stereotype. Psychological Bulletin, 110, 109-128.

Farber, S. L. (1981). Identical twins reared apart: A reanalysis. New York: Basic Books.

Feingold, A. (1992). Good-looking people are not what we think. Psychological Bulletin, 111, 304-341.

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

Gottlieb, G. (1998). Normally occurring environmental and behavioral influences on gene activity: From central dogma to probabilistic epigenesis. Psychological Review, 105, 792-802.

Hetherington, E. M., Reiss, D., and Plomin, R. (Eds.). (1994). Separate social worlds of siblings: The impact of nonshared environment on development. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Hettema, J. M., Neale, M. C., and Kendler, K. S. (1995). Physical similarity and the equal-environment assumption in twin studies of psychiatric disorders. Behavior Genetics, 25, 327-335.

Hollingshead, A. B., and Redlich, F. C. (1958). Social class and mental illness; A community study. New York: Wiley.

Howe, M. J. A., Davidson, J. W., and Sloboda, J. A. (1998). Innate talents: Reality or myth? Behavioral and Brain Sciences, 21, 399-442.

Jones, S. (1991). The language of genes [The BBC Reith Lectures]. London: British

Broadcasting Corporation.

Joseph, J. (1998). The equal environment assumption of the classical twin method: A critical analysis. Journal of Mind and Behavior, 19, 325-358.

Juel-Nielsen, N. (1980). Individual and environment: Monozygotic twins reared apart. New York: International Universities Press.

Kamin, L. J. (1974). The science and politics of IQ. Potomac, Maryland: Lawrence Erlbaum.

Langlois, J. H., Kalakanis, L., Rubenstein, A. J., Larson, A., Hallam, M., and Smoot, M. (2000). Maxims or myths of beauty? A meta-analytic and theoretical review. Psychological Bulletin, 126, 390-423.

Lewontin, R. C., Rose, S., and Kamin, L. J. (1984). Not in our genes. New York: Pantheon Books.

Loehlin, J. C., and Nichols, R. C. (1976). Heredity, environment, and personality : A study of 850 sets of twins. Austin, Texas: University of Texas Press.

Machin, G. A. (1996). Some causes of genotypic and phenotypic discordance in monozygotic twin pairs. American Journal of Medical Genetics, 61, 216-228.

Mandler, G. (1996). The situation of psychology: Landmarks and choicepoints. American Journal of Psychology, 109, 1-35.

McGue, M., and Lykken, D. T. (1992). Genetic influence on risk of divorce. Psychological Science, 3, 368-373.

Moos, R. H. (1996). Understanding environments: The key to improving social processes and program outcomes. American Journal of Community Psychology, 24, 193-201.

Morris-Yates, A., Andrews, G., Howie, P., and Henderson, S. (1990). Twins: A test of the equal environments assumption. Acta Psychiatrica Scandinavica, 81, 322-326.

Newman, H. H., Freeman, F. N., and Holzinger, K. J. (1937). Twins: A study of heredity and environment. Chicago, Illinois: University of Chicago Press.

Ogbu, J. U. (1978). Minority education and caste: The American system in cross-cultural perspective. New York: Harcourt Brace Jovanovich.

Pinel, J. P. J. (1997). Biopsychology (third edition). Boston, Massachusetts: Allyn and Bacon.

Plomin, R. (1990). Nature and nurture: An introduction to human behavioral genetics. Pacific Grove, California: Brooks/Cole.

Plomin, R., and Daniels, D. (1987). Why are children in the same family so different from one another? Behavioral and Brain Sciences, 10, 1-16.

Plomin, R., DeFries, J. C., and McClearn, G. E. (1990). Behavioral genetics: A primer (second edition). New York: W. H. Freeman and Co.

Reis, H. T., Wheeler, L., Spiegel, N., Kernis, M. H., Nezlek, J., and Perri, M. (1982). Physical attractiveness in social interaction: II. Why does appearance affect social experience? Journal of Personality and Social Psychology, 43, 979-996.

Rose, R. J. (1982, February). Separated twins: Data and their limits. Science, 215, 959-960.

Ruel, M. T., Rivera, J., Habicht, J. P., and Martorell, R. (1995). Differential response to early nutrition supplementation - Long-term effects on height at adolescence. International Journal of Epidemiology, 42, 404-412.

Schiff, M., and Lewontin, R. (1986). Education and class: The irrelevance of IQ genetic studies. New York: Oxford University Press.

Shields, J. (1962). Monozygotic twins: Brought up apart and brought up together. London: Oxford University Press.

Smith, R. T. (1965). A comparison of socioenvironmental factors in monozygotic and

dizygotic twins, Testing an assumption. In S. G. Vandenberg (Ed.), Methods and goals in human behavior genetics (pp. 45-61).New York: Academic Press.

Spitz, E., and Carlier, M. (1996). La méthode des jumeaux de 1875 a nos jours. Psychiatrie de l'Enfant, 39, 137-159.

Taylor, H. F. (1980). The IQ game: A methodological inquiry into the heredity-environment controversy. New Brunwick, New Jersey: Rutgers University Press.

Tucker, W. H. (1997). Re-reconsidering Burt: Beyond a reasonable doubt. Journal of the History of the Behavioral Sciences, 33, 145-162.

von Bracken, H. (1934). Psychologische Untersuchungen an Zwillingen [Psychological investigations of twins]. In O. Klemm (Ed.), Bericht über den XIII. Kongress der Deutschen Gesellschaft für Psychologie [Proceedings of the 13th Congress of the German Society for Psychology] (pp. 117-119). Leipzig: Gustav Fischer.

ADDENDUM

I add a comment on an argument sometimes made about some apparent results in twin studies. I call these secondary effects and I refer to them in the paper, e.g., that identical twins show similar rates of divorce or time of first intercourse. I argued that the physical similarity of these twins is the most likely explanation of these “effects.” It has been maintained by some that these effects must be genetic, since they show a similarity in the behavior of monozygotic twins. However, a moment’s thought tells us that many if not most human traits could be traced back to genetic causes by such an argument. The human hand produces such phenomena as handwriting, knitting and gestures that vary with cultures, even though they are of course based on a genetically determined hand; other examples abound. Just because the human physical constitution is primarily a function of our genetic history does not mean that traits or habits developed by our physical make-up are themselves genetically determined.