Heredity, Environment, and School Achievement

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Johnny is brighter than Billy. He seems to learn more easily, he does better in school, and he scores higher on tests of ability and school achievement. A natural response to such an everyday observation is to ask, "What treatment has Johnny had that Billy has missed? Perhaps if we give Billy these advantages his behavior will become more like Johnny's." This same comparison is frequently made between students in different school systems, different racial or ethnic groups, different states and different countries; with the same natural desire to reduce the differences by giving to the poorer the advantages of the superior.

The differences between some of these groups are fairly large—for example, 3.7 per cent of high school juniors in Connecticut score high enough on a test of educational development to be commended in the National Merit program while only 0.6 per cent of the students in Arkansas score at this level (National Merit Scholarship Corporation, 1965). If we could just find out what it is about living in Connecticut that makes students so smart, and if we could give it to the students in the rest of the country, we could more than double the nation's supply of high level talent. This is certainly a worthwhile goal to strive for, but where do we start? There are a lot of nice things about Connecticut that might serve as clues. For example, in Connecticut there are 242 cars per square mile spewing carbon monoxide and other noxious gases into the atmosphere while in Arkansas there are only 12 cars per square mile. This finding cross-validates nicely—for example, Massachusetts, another state with a high proportion of able students, has 230 cars per square mile while Alabama, another state relatively lacking in talented students, has only 25 cars per square mile.

I bring up the automobile example not just to be funny but also to illustrate that ecological correlations can arise in such indirect ways that they offer only vague clues that need to be

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checked out with other evidence. Connecticut and Massachusetts also have higher teacher salaries and spend more per student for school facilities than do Arkansas and Alabama, but this doesn't necessarily mean that increasing school expenditures will increase student performance. We need to look for other supporting evidence and for other rival hypotheses to explain the observed variations in ability.

There are three main factors or types of variables that seem likely to have an important influence on ability and school achievement. These are (a) the school factor or organized educational influences; (b) the family factor or all of the social influences of family life on a child; and (c) the genetic factor. In addition to these three main factors one might also add nutritional factors, community influences, and so on. According to the common sense methodology of first identifying factors responsible for the performance of superior individuals, then giving these advantages to everyone, thereby reducing individual differences, our first task is to determine the extent to which individual differences in ability are due to differences in the major factors or types of influences. This will help us know where to look when we try to isolate the particularly salient events that are responsible for individual differences and to understand the mechanisms involved. When we look at the task from this long-term perspective, it is evident that we have a long way to go.

The separation of the effects of the major types of influences has proved to be extraordinarily difficult, and all of the research so far has not resulted in a clear-cut conclusion. If we were to poll a representative group of educational research specialists concerning their best guess as to which of the three types of influence just mentioned—the school factor, the family factor, and the genetic factor—is responsible for the largest proportion of individual differences in, say, verbal ability among high school students in the United States, such a poll would not even give a plurality of the votes to one factor over the other two.

This messy situation is due primarily to the fact that in human society all good things tend to go together. The most intelligent parents—those with the best genetic potential—also tend to provide the most comfortable and intellectually stimulating home environments for their children, and also tend to send their children to the most affluent and well-equipped schools. Thus, the ubiquitous correlation between family socio-economic status and school achievement is ambiguous in meaning, and isolating the independent contribution of the factors involved is difficult. However, the strong emotionally motivated attitudes and vested interests in this area have also tended to inhibit the sort of dispassionate, objective evaluation of the available evidence that is necessary for the advance of science.

THE SCHOOL FACTOR

It seems almost self-evident that there should be a large school effect on measures of ability and academic achievement. Universal education in the United States has obviously been largely responsible for producing the highly literate and capable population we see today, and without continued educational efforts we would undoubtedly regress to more primitive levels. But the very fact that education is so widespread and so obviously successful may reduce its importance as a source of individual differences in ability in this country. It may be that educators, rightly concerned with improving the resources with which they work, tend to exaggerate the importance of relatively minor differences in educational facilities and to forget how hard it is to improve on "Mark Hopkins on one end of a log and the student on the other." Thus it is legitimate to ask to what extent individual differences in ability in this country are due to differences in educational experiences without questioning the importance of the educational effort for the population as a whole.

Recent studies of school effects have shown a rather monotonous tendency to find that differences in school experiences have little relationship to differences in student performance after all the relevant background factors have been controlled. This is surprising because improving student performance is the main purpose of the schools and it stands to reason that schools with more resources should do a better job than schools with less resources. When Sandy Astin and I first started our studies of college effects we expected to find large differences in the effects of different colleges and we were very concerned with developing adequate controls for student input so that these effects would show up. But the more we controlled for student input the smaller the differences between the graduates at different colleges became. After failing to find substantial differential college effects on such variables as Obtaining a PhD (Astin, 1962), Graduate Record Examination Score (Nichols, 1964), Career Choice (Astin, 1965), and Personality Inventory Scores (Nichols, 1967), we have now become concerned with how to keep from partialling out whatever small differential college effects there may be along with the much larger differences in student input.

One might say, as we did after the fact, that large school effects should not be expected for college-age students. By the time a person is 17 years old, the major influences have already been operating for a long time, and the students have likely developed defenses against noxious stimuli and methods of compensating for environmental inadequacies. It seems reasonable to assume that we will have to look to earlier ages for substantial school effects.

The recent study of Equality of Educational Opportunity by the U.S. Office of Education (Coleman, et al., 1966; Nichols, 1966)—the well known Coleman report—focused on the period from the first through twelfth grade, where school effects might more reasonably be expected. Yet the data from this large study led the authors to conclude the following: "Variations in school quality are not highly related to variations in achievement of pupils. . . . The school appears unable to exert independent influences to make achievement less dependent on the child's background" (p. 297). Thus, the same rationalization of negative results that we used for colleges is also used here—the really formative influences have already taken place; enduring individual differences in ability are already established before students enter first grade.

I expect this sort of reasoning was one of the major justifications for the Head Start program. Since compensatory education programs for older disadvantaged students did not in general result in dramatic improvements in performance, it seemed reasonable to introduce a pre-school program to reach the children in the formative period before the maladaptive behavior patterns had become solidified. Studies of the results of the Head Start experience suggest that the gains from this program may be temporary and that the head start tends to be lost in a few months (Wolf & Stein, 1966). Again, an educational experience does not seem to produce enduring individual differences in ability and our attention is directed toward even earlier events.

In the United States where some sort of education is available to everyone and the mass media continually bombard us with seductive conceptual material—in other words, where very few suffer really drastic educational disadvantage—the largely negative results of studies of school effects suggest that the family factor and the genetic factor are likely the major sources of individual differences in ability.

CRITICAL EARLY EXPERIENCES

Perhaps the best evidence for the importance of early experience for later intellectual development comes from studies of animals. Hebb (1949) has found that animals reared in a stimulus-rich environment show enduring superiority in adaptive response over genetically equivalent animals that were deprived of the early stimulation. Even very brief handling experiences of infant mice, if they occur at fairly sharply defined critical periods, will have pronounced effects on the animals' reaction to stress for the rest of their lives. Denenberg is transplanting fertilized ova from one strain of mouse to another and is finding that some factors that had previously been thought to be genetic are actually dependent on the intra-uterine environment (personal communication, but see Denenberg, 1966).

The human situation is undoubtedly much more complicated than that of rats and mice, and it is dangerous to generalize more than the gross principle that early experience can be very influential on later behavior, and perhaps that there are critical periods when certain experiences are more salient than at other times.

We have very little information about what early experiences are critical in human development. This is a field that deserves much more attention than it has received, and it will undoubtedly be better worked in the future as educational efforts are directed at ever earlier age levels.

THE FAMILY FACTOR

One clue to the importance of a particular configuration of early experiences comes from studies of the effects of birth-order, which has recently become a popular area of research (Altus, 1966). Birth order is a particularly felicitous variable, since valid information about it is easily obtained at almost any age, and it reveals a great deal about the early life of the person. For example, from observing my own children it is obvious that the family experience of the older of two brothers who are two years apart in age is quite different from the experience of the younger. We became interested in this problem when we noticed that the talented students in the Merit Program tended to be the first-born in their families. Typical findings are shown in Table 1. Among Merit Finalists from two-child families there are about twice as many first-born as second-born. In three-child families there are about as many first-born as second- and third-born combined, and the second-born outnumber the third-born. The same trend holds true for four- and five-child families. We have come to think of this birth-order effect in talented students as an established fact, since Terman (1925) also found it in his gifted group and it holds in five different large groups of Merit participants. The same predominance of early-born children was observed in a group of 600 talented Negro students (Roberts & Nichols, 1966).

There are three possible explanations for these findings: (a) some physiological effects of the more difficult birth or younger age of the mother of earlier-born children may influence intelligence, (b) the differential family environment of early- and later-born children may affect the development of intelligence, or (c) the relationship may be an artifact of varying birth rates, differential participation in scholarship programs, or some other spurious influence.

To study these problems we asked the 800,000 students who took the

TABLE 1

Percentage of Merit Finalists Selected in 1964 in Each Birth Position for Two-, Three-, Four-, and Five-Child Families

Number of Children in Family	*Number of Finalists*	*Birth Position* *1*	*2*	*3*	*4*	*5*	*Chi-Square*
2	568	66	34				60.90*
3	414	52	31	17			79.59*
4	244	59	21	12	8		159.65*
5	85	52	22	9	11	6	60.10*

* $p < .001$

NMSQT in 1965 to indicate the number, age, and sex of their siblings. These data allowed us to study the relationship of the test score to birth-order, sex of sibling, and spacing.

The results (as yet unpublished) confirmed the findings concerning birth-order among Merit Finalists. The earlier-born the students were in their family, the higher their average test score; and this relationship held for all family sizes for both boys and girls regardless of the sex or spacing of the siblings. For a given family size and birth-order, the sex of the sibling had little relationship to the test score for either boys or girls, but spacing of the siblings was quite important. The closer in age the nearest sibling, the lower the test score tended to be; and this tendency was more pronounced if the sibling was older than if he was younger.

The relationship between birth-order and test score among all participants in our screening test seems to indicate that the excess of early-born among Merit Finalists is not an artifact of greater participation of the older children in a family or of varying birth rates; and the relationship of sibling spacing to test score seems to favor a psychological rather than a physiological explanation for the birth-order findings.

The available data offer no hint as to whether it is the greater parental attention often devoted to the first-born children in a family, the competitive interaction between the siblings themselves or some other factor in the situation that puts the younger sibling at a developmental disadvantage. However, the birth-order findings do provide an exciting clue to the great mystery of intellectual development. The mean difference between older and younger children in closely spaced families is almost as large as the difference between the students in Connecticut and those in Arkansas. So, if we could discover what makes the older siblings so smart and give it to the younger siblings, the result for the population as a whole would not be negligible.

Another example of the sort of evidence that points to the importance of early experience for the development of intelligence is the study by Wolf (1965) of specific early environmental experiences and later achievement. He reasoned that if the typical correlation betwen family socio-economic status and student achievement of .40 to .50 is mediated in part by differential experiences of children in families at different socio-economic levels, then the correlation should be higher if a direct assessment were made of the child's environment rather than indirectly through characteristics of the parents. Ratings of environmental stimulation based on parental reports were found to correlate .69 with measured intelligence and .80 with school achievement. These correlations, which seem almost too high to be true, suggest that differential early stimulation accounts for part of the differences in performance of students from different socio-economic levels.

So there are clear indications that the family factor is an important source of individual differences in ability, but as yet we don't know just what the critical experiences are, or much about their timing except that they occur very early in life—probably before age three or four.

THE GENETIC FACTOR

In contrast to the scant information about the family factor there is fairly convincing evidence that the genetic factor is a major determinant of individual differences in ability. Erlenmeyer-Kimling and Jarvik (1963) have cleverly plotted the results of 52 studies from the literature to show that the similarity between pairs of people increases steadily as their genetic relationship increases from a correlation of .00 for unrelated persons reared apart through .50 for parent-child and sibling pairs (including fraternal twins) to .87 for identical twins reared together.

In our study of twins that participated in the National Merit Talent Search (Nichols, 1965) we found an intra-class correlation of .87 for the composite screening test score for 687 sets of identical twins and a correlation of .63 for 482 sets of fraternal twins. There are so many methodological problems with twin correlations that it is dangerous to use these correlations to compute exact heritability coefficients, but it is difficult to conclude that there is not a sizable genetic component in ability measures. Our findings are typical of twin correlations found in most previous twin studies—all using different tests and many conducted in different languages.

In addition to the twin data, another convincing line of evidence for the importance of the genetic factor comes from adopted child studies where the intelligence scores of the child have been found to be much more related to the educational level of the true mother, who did not raise the child, than to that of the foster mother who did raise the child (Honzik, 1957).

A rough ordering of the major factors in terms of their importance for determining individual differences in ability in the United States might be—going from least to most important—the school factor, the family factor, and the genetic factor. It is interesting to note that this is exactly the reverse order from a ranking in terms of the amount of effort and attention devoted to these factors in our attempts to improve the performance of our young people. Indeed, it is probably this very distribution of effort that has resulted in the findings we have discussed. The more we succeed in equalizing the effects of a particular factor in the population, the less important that factor will become as a source of individual differences.

Educators typically react negatively to evidence indicating the importance of the genetic factor, undoubtedly because of the apparent pessimistic implications. To the extent that ability is genetically determined, it would seem that there is that much less hope for those of us who are already born.

However, when we understand more about the genetic mechanisms, these pessimistic implications may disappear. For example, studies of the genetics of behavior of mice, exemplified by the work of McClearn (1964), show that there is a large interaction between heredity and environment. The effect on behavior of a particular environmental experience differs, depending on the genotype of the animal. To the extent that this is also true of humans, there are important implications for education. The same educational experiences may not be optimal for everyone—which is something that educators have been saying recently—and educational effects may be considerably enhanced once we know enough to administer the right educational experience at the right time to the right genotype.

REFERENCES

Altus, W. C. Birth order and its sequelae. *Science,* 1966, *151,* 44-49.

Astin, A. W. "Productivity" of undergraduate institutions. *Science,* 1962, *136,* 129-135.

Coleman, J. S., Mood, A. M., Campbell, E. Q., et al. *Equality in educational opportunity.* Washington, D.C.: Government Printing Office, 1966.

Denenberg, V. H. Animal studies on developmental determinants of behavioral adaptability. In Harvey, O. J. (Ed.), *Experience, structure and adaptability.* New York: Springer, 1966.

Erlenmeyer-Kimling, L., & Jarvik, L. F. Genetics and intelligence: a review. *Science,* 1963, *142,* 1477-1479.

Hebb, D. O. *The organization of behavior.* New York: Wiley, 1949.

Honzik, M. P. Developmental studies of parent-child resemblance in intelligence. *Child Development,* 1957, *28,* 215-228.

McClearn, G. E. Genetics and behavior development. In Hoffman, M. L., and Hoffman, L. W., *Review of child development research.* New York: Russell Sage, 1964.

National Merit Scholarship Corporation. *Guide to the National Merit Scholarship Program.* Evanston, Ill.: National Merit Scholarship Corporation, 1965.

Nichols, R. C. Effects of various college characteristics on student aptitude test scores. *Journal of Educational Psychology,* 1964, *55,* 45-54.

Nichols, R. C. The National Merit twin study. In Vandenberg, S. G. (Ed.), *Methods and goals in human behavior genetics.* New York: Academic Press, 1965.

Nichols, R. C. Schools and the disadvantaged. Review of J. S. Coleman, et al., *Equality of educational opportunity. Science,* 1966, *154,* 1312-1314.

Nichols, R. C. Personality change and the college. *American Educational Research Journal,* 1967, *4,* 173-190.

Roberts, R. J., & Nichols, R. C. Participants in the National Achievement Scholarship Program for Negroes. *NMSC Research Reports,* No. 2, 1966.

Terman, L. M., et al. *Genetic studies of genius, Vol. 1: Mental and physical traits of a thousand gifted children.* Palo Alto, Calif.: Stanford University Press, 1925.

Wolf, M., & Stein, A. Six months later: a comparison of children who had Head Start, summer 1965, with their classmates in kindergarten. Washington, D.C.: Office of Economic Opportunity. *Final Report of Project,* 141-161.

Wolf, R. The measurement of environments. In *Proceedings of the 1964 Invitational Conference on Testing Problems.* Princeton, New Jersey: Educational Testing Service, 1965.