Family Configuration and Intelligence

Variations in scholastic aptitude scores parallel trends in family size and the spacing of children.

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In 1962 the average Scholastic Aptitude Test score of high school seniors was 490. In 1975 it barely surpassed 450. This decline has been steady over the last 12 years, and it appears to be continuing. Some educational authorities blame it on television, on the erosion of interest in language skills, or on a widespread craving for freedom of expression that is at odds with disciplined learning, but there is no evidence to support any of these opinions. Nor is there any evidence that the decline in SAT averages is due to the rising numbers of poor and minority students who have taken the tests. In fact, the proportion of such students remained stable in the last several years while SAT scores continued to decrease (*1*).

In all likelihood a number of diverse conditions converged to precipitate the decline. In this paper, however, the focus is entirely on one set of such factors, those associated with changing family patterns. I shall try to show generally that variations in aggregate intelligence scores are closely associated with variations in patterns of family configuration, and that these aggregate family factors are deeply implicated in the declining SAT scores as a special case of a general phenomenon that manifests itself also in a variety of national, ethnic, regional, racial, and sex differences in intellectual test performance. For the purpose of this argument, I will first summarize a recent theoretical analysis that specifies the conditions under which family configuration may foster or impede intellectual growth. I will then examine some relevant empirical findings, and finally return to the special case of the SAT's.

Table 1 is based on a study by Breland (*2*) in which the averages of nearly 800,000 candidates on the National Merit Scholarship Qualification Test (NMSQT) were examined as a function of family size and birth order. Five features of these results are of particular significance: (i) NMSQT scores generally decline with increasing family size; (ii) within each family size they decline with birth order; (iii) the rate of decline decreases with successive birth orders; (iv) there is a discontinuity for the only child, who scores below a level that would be expected had intelligence declined monotonically with increasing family size; (v) twins have comparatively low scores.

Such effects of birth order and family size on intellectual test performance have been recently explicated in a theory called the confluence model (*3*). In this model, Markus and I try to capture the effects of the immediate intellectual environment on intellectual growth, and to specify how individual differences emerge in the social context of the family. The basic idea of the confluence model is that within the family the intellectual growth of every member is dependent on that of all the other members, and that the rate of this growth depends on the family configuration. Different family configurations constitute different intellectual environments. "Intellectual environment" can be thought of in this context as being some function of the average of the absolute intellectual levels of its members. Note that we are not considering IQ, which is a quantity relative to age, but rather an absolute quantity such as mental age. If the intellectual environment is conceived as an average of all the members' absolute "contributions," then it changes continually as the children develop, and it manifests the most dramatic changes when there is an addition to or departure from the family. Of course, abrupt changes in the environment need not have immediate effects.

The confluence model defines intellectual growth of the individual as a function of his age and represents changes in the rate of this growth by a parameter α_τ which is a function of the intellectual environment in the family at time τ. The following examples illustrate, in a simplified form, the dependence of intellectual growth on the changing family configuration. For the purpose of these examples consider the absolute intellectual levels of the parents to be 30 arbitrary units each, and of the newborn child to be zero. Thus, the intellectual environment at the birth of the first child has an average value of 20. Suppose the second child is born when the intellectual level of the firstborn reaches 4. The second born then enters into an environment of $(30 + 30 + 4 + 0)/4 = 16$. (Note that since the intellectual environment is an average of the absolute intellectual levels of all family members, the individual is included as a part of his own environment.) If a third child is born when the intellectual level of the firstborn has reached, say, 7 and that of the secondborn is at 3, the family intellectual environment will then be reduced to 14.

These examples illustrate a number of significant consequences that the confluence model predicts. It might appear from these examples that intellectual environment should decline with birth order. That is not so. In itself birth order is not an important variable. The model predicts that its effects are mediated entirely by the age spacing between siblings. Observe that if the second child is not born until the first reaches an intellectual level of 24, for example, then the newborn enters an environment of $(30 + 30 + 24 + 0)/4 = 21$, which is more favorable than the one of 20 entered by the firstborn. Hence, with large enough age gaps between siblings (allowing sufficient time for the earlier born to mature), the negative effects of birth order can be nullified and even reversed.

In principle, the negative effects of family size can also be overcome by age spacing between children. If each child were to be born only after its predecessors reached maturity (to take an extreme example), each successive sibling would enter a progressively more favorable environment, and the average intellectual levels would increase with family size. Of course, older children tend to leave home eventually. Furthermore, biological constraints set limits on the covariation of family size and spacing. Demographic data show that birth inter-

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vals invariably decline as family size increases.

The examples above deal only with environment at birth. The confluence model considers the intellectual growth process over time and evaluates all changes in the rates of family members' growth that are caused by the resulting changes in intellectual environment (*4*).

The growth parameter α_τ represents an important aspect of this analysis, for it reflects all significant changes in the individual's intellectual environment. But it also reflects the confluent nature of intellectual development within the family context. The intellectual development of all family members is affected by the common familial intellectual milieu. Therefore α_τ is the same for all members at the point in family history τ, a feature of the model which underscores the mutuality of intellectual influences among family members. It may be noted that the later these influences occur in the individual's life, the smaller is their effect (*5*).

Representing intellectual environment as some function of the average absolute intellectual levels within the family is obviously a simplification of what is an enormously complex process. Clearly, intellectual growth will not be greatly enhanced by a highly favorable environment if there is no interaction between the child and the people around him. The influence of the parents' and siblings' intellectual levels on the child's growth is necessarily mediated by diverse processes of social interaction that vary from family to family. Ideally the parameter α_τ should represent not only the intellectual levels of the family members but also the amount of time each family member spends with the child. The nature of social interaction in the home also influences intellectual growth; a game of tag may not be as conducive to the development of intelligence as a game of chess. This sort of articulation of the parameter α_τ is impracticable at present, not only because of the formal complexity that it would entail but also because we do not yet know how various forms of social interaction contribute to intellectual growth. It will be shown, however, that even though the confluence model ignores much of the richness of the social processes that mediate intellectual growth, it leads to a variety of empirically supported inferences about differences in intellectual test performance among individuals and groups.

Table 1. Mean scores on the National Merit Scholarship Qualification Test, 1965, by place in family configuration. [Data from (*2*)]

Family size	Birth order 1	2	3	4	5
1	103.76				
2	106.21	104.44			
3	106.14	103.89	102.71		
4	105.59	103.05	101.30	100.18	
5	104.39	101.71	99.37	97.69	96.87
Twins	98.04				

Family Size

In addition to Breland's study of NMSQT candidates, there are three other studies in which the intellectual test performance of large populations was examined for its relationship to the sort of family variables that, according to the confluence model, influence intellectual development. The earliest of these was carried out in Scotland on 70,000 school children (*6*). The more recent ones come from France (*7*) and the Netherlands (*8*) and report data for 100,000 and 400,000 individuals respectively. They are summarized in Fig. 1. To make them roughly comparable, all the averages have been converted into standard deviation units

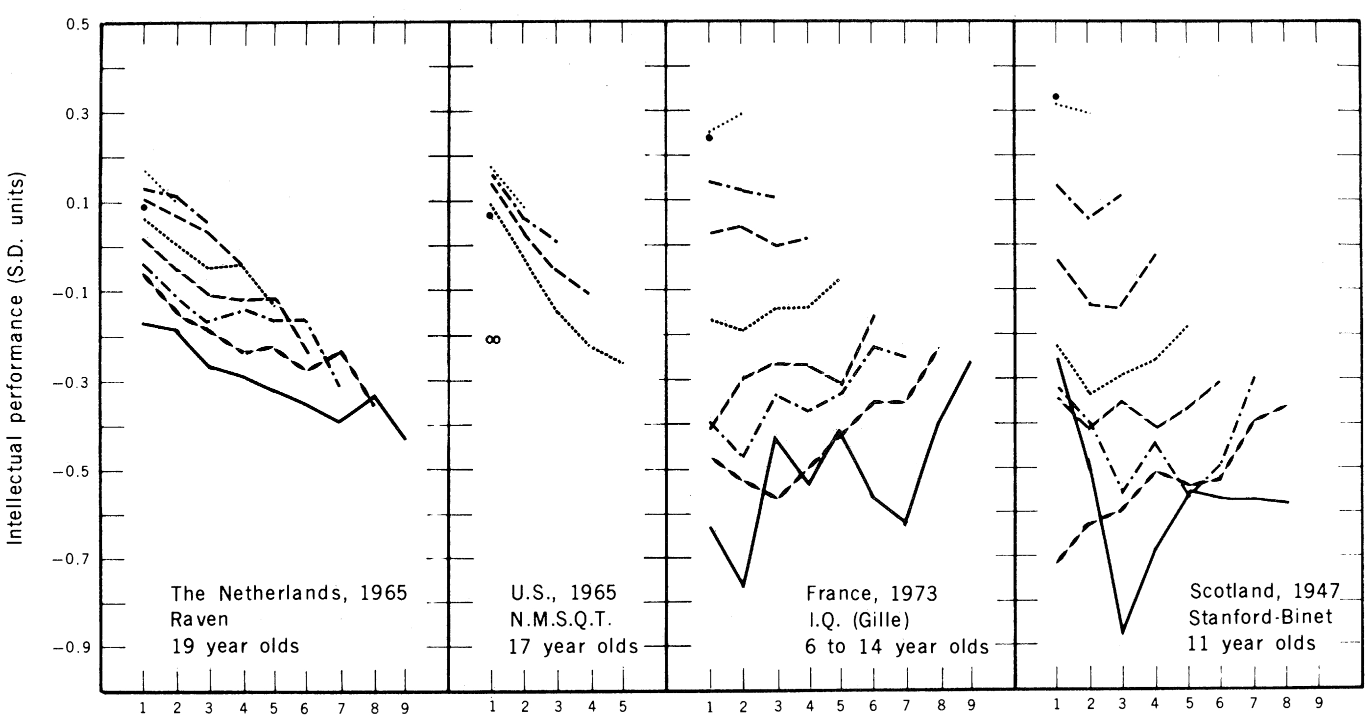


Fig. 1. Intellectual performance of four large populations, plotted as function of birth order and family size. Separate curves in each graph represent different family sizes, which can be read from the last birth order on each curve. Solid circles represent only children. The double open circle in the U.S. data represents twins. The years show when data were collected. The means of the Dutch, American, French, and Scottish data sets are 2.82, 102.5, 99.2, and 36.74 respectively. The corresponding standard deviations are 1.43, 21.25, 14.53, and 16.10.

$[X' = (X - \bar{X})/\sigma$, where X's are cell means and $\bar{X}$'s and σ's are the means and the standard deviations of the samples]. There are a number of interesting similarities and differences among the four samples which can be understood if we analyze them in terms of the confluence model.

All four sets of data, even though they are derived from different tests of intellectual performance, different age groups, different cohorts, and different countries, indicate that intellectual level generally declines with family size. Even in the NMSQT sample, which consists of promising students, there is decline with family size. As a result of the selective factor, however, the effect is attenuated in that sample. In others the effect is quite substantial. In the French and Scottish samples the difference between the IQ's of children from the smallest and the largest families is about one standard deviation (15 points).

It is well known that family size differs across socioeconomic strata and so does intellectual test performance. The possibility that socioeconomic factors mediated these results must be considered. Three socioeconomic levels (SES) were differentiated in the Dutch sample, six in the French. Both sets of data (Fig. 2) reveal that intellectual performance declines with increasing family size independently of SES. In the French sample the partial correlation between family size and IQ was −.45. In fact, it appears that SES contributes to the family size effects only a little, for the correlation rises to only −.47 when SES is allowed to vary freely. Needless to say, socioeconomic status does affect intelligence scores, a fact that is clear from Fig. 2. The partial correlation between them is .66.

Birth Order and Spacing of Siblings

It is strikingly apparent in Fig. 1 that in the Dutch and American samples intellectual test performance declines with birth order whereas in the French and Scottish there is no such decline (*9*). According to the confluence model, the effects of birth order are totally mediated by the age gaps between successive children, hence these differences in the effects of birth order must be associated with differences in age gaps.

While there is no specific and direct empirical information about age gaps in the four samples, information about national averages in these countries taken from census data can be used. Unfortunately, data on birth intervals are not collected uniformly. (In Scotland no such data were tabulated at all in 1936, when the children in the Scottish sample were born.) Hence, comparisons with regard to birth intervals must rely on indirect indices.

One reliable correlate of birth intervals is, of course, birthrate. When birthrate is high or rising, intervals between successive births are normally quite short; during a period of low or declining birthrate they are longer. For the Dutch subjects (who were born in 1944 to 1946) the corresponding birthrate was rising, from 24.0 in 1944 to 30.2 in 1946. The birthrate in the United States in the year 1948, when most of the NMSQT respondents were born, was 24.2 and also rising. For the French cohorts, however, the birthrate averaged over the years of their births was 18.2 and declining, and the Scottish birthrate in 1936 was 17.9 and declining as well (*10*). Hence the differences in intellectual performance associated with birth order (Fig. 1) are entirely consistent with the pattern of differences in birthrates in the four countries. Where birth order is least detrimental to intellectual performance, namely in Scotland, is also where birthrate is lowest.

National averages for intervals between successive births in completed families, that is, families known to have had their last children, have been collected only recently, and they are available for the cohorts from which the French sample was drawn (*11*). The intervals for completed families of two to six children are reproduced in Fig. 3. They are generally quite long. For some of the points in Fig. 3 comparable data are available from U.S. births of about 1959 (*12*) and from Dutch births of about 1944, both estimated from data on births since marriage tabulated by birth order (*13*). The American and Dutch intervals are considerably shorter than the French. For example, the intervals between the first and second births in American and Dutch two-child families were 45.7 and 44.6 months respectively; the French interval was over 60 months. The intervals between the second and third births in American and Dutch three-child families were 45.8 and 47.0 months, again more than one year shorter than in the French. Hence the pattern of differences in birth order effects (Fig. 1) is paralleled by a pattern of differences in birth intervals in the four countries such as the confluence model leads us to expect. For the Dutch and American cohorts, in which there is a general decline in intellectual performance with birth order, birth intervals seem generally to be short. For the French and Scottish samples, which do

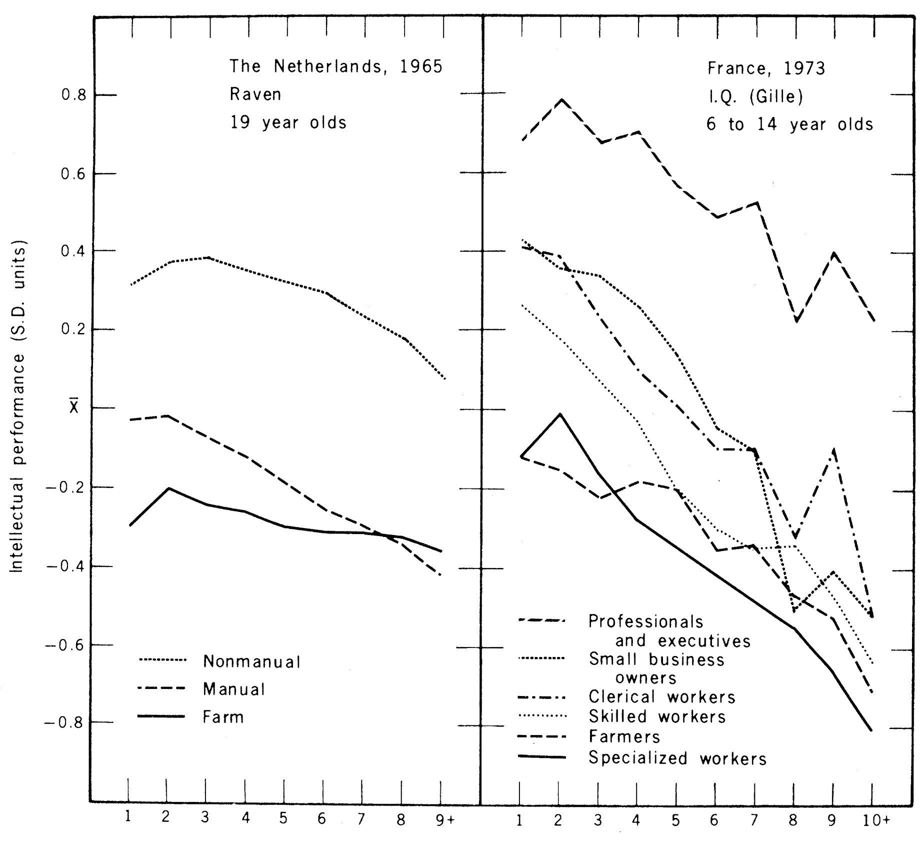


Fig. 2. Relation of family size and socioeconomic status to intellectual performance in the Netherlands and in France.

not show such a decline, they are substantially longer.

An interesting trend is observed in Fig. 3: each successive child appears to be separated from the preceding sibling by an increasingly longer gap. Last children, therefore, come after the longest gap. This trend may explain why there is a quadratic component in the birth order curves shown in Fig. 1, and why there seems to be in some cases an upswing in intelligence for later-born children (*14*).

One other important factor no doubt contributed to the pattern of results in the French and Scottish birth order data. These scores come from children 6 to 14 years of age and 11 years of age respectively. Obviously, children of those ages who are among the eldest in large families cannot be very widely separated in age from their siblings. The youngest in large families, however, can come from sibships with large or small gaps, hence there is no reason to suppose that the gaps of the later-born children differed from the national averages, which we noted were relatively high. If the short age gaps of earlier-born children depress their intellectual performance, their advantage in order of birth could be nullified. Longer gaps between later-born children in these samples may compensate for the depressing effects of late birth order. Together, these factors would produce a pattern of birth order effects such as was found in the French and Scottish samples. These considerations suggest that the differences in birth order effects among the four national samples in Fig. 1 are associated with differences in age gaps.

There is some other more direct information which indicates that children with large age gaps between them and their younger siblings attain higher intellectual levels than children close in age to younger siblings. In a family of two children, for example, the larger the age separation the longer the older child can remain in an environment undiluted by the presence of an intellectually immature sibling. Long birth intervals give older children the benefits of being in a small family for a longer period of time and during an early phase of growth, which is sensitive to environmental effects. It is also to the advantage of the younger child to postpone its birth, because the later it arrives the more mature will be the environment which it enters at birth and in which it will develop. Higher IQ's for pairs of widely spaced children than for closely spaced pairs were indeed found by Tabah and Sutter (*15*). More recently, an extensive study of perinatal effects (*16*) found that children born after long intervals score four points higher on the Stanford-Binet scale than children born after shorter intervals, a difference that was independent of the socioeconomic status of parents.

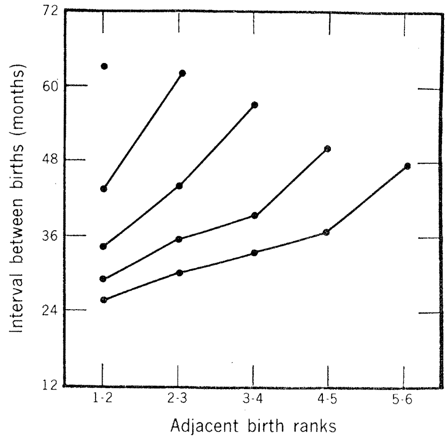


Fig. 3. Intervals between successive children in completed French families of two to six children, according to a 1962 survey (*11*).

Evidence from Twins

Twins score consistently and substantially lower on intelligence tests and other tests of intellectual performance than do nontwins. For example, in the National Merit Scholarship sample (*2*) twins achieved an average score of 98.0, singly born children an average of 102.57. Tabah and Sutter (*15*) report an average IQ of 89.2 for twins and 101.2 for singly born children among French 6- to 12-year-olds. Other studies agree with these findings (*17, 18*). Record, McKeown, and Edwards (*19*) found an average verbal reasoning score of 95.7 for twins and 91.6 for triplets, which are deficits of .30 and .58 S.D. unit. Admittedly, biological factors may be involved here, but deficits for twins and larger multiple births would also be expected according to the confluence model. Twins have of course the shortest possible gaps between successive siblings. Thus, a family with two singly born children and a family with twins represent quite different intellectual environments. For twins who are the first offspring the intellectual environment at birth is $(30 + 30 + 0 + 0)/4 = 15$. In a two-child family the environment of the first-born is 20, and it must be higher than 15 at the birth of the second child because $(30 + 30 + x + 0)/4 > 15$, since $x > 0$. Hence, with other factors constant, the intellectual environment for twins must necessarily be lower than for either of two singly born siblings.

Perhaps the most important evidence of environmental effects on the intellectual growth of twins comes from another aspect of the Record-McKeown-Edwards study (*19*). It follows from the confluence model that the intellectual performance of twins who were separated early in life should be higher than of twins reared together. Record *et al.* report that twins whose co-twins were stillborn or died within four weeks achieve nearly the same average intelligence as nontwins. Table 2 reproduces these data together with the average birth weights of the subjects. The fact that the birth weights of twins who both survive are higher than of those of whom one dies early suggests that physiological factors, for example oxygen deficiency, that are postulated as explaining the relatively low intelligence of multiple-birth children may have been exaggerated (*20*).

Parental Absence

It follows directly from the confluence model that a one-parent home constitutes an inferior intellectual environment and should result in intellectual deficits, and that early loss of a parent should produce greater deficits than a loss occurring at a later age. In most studies of this effect the absent parent is the father, and their results agree with these inferences (*16, 21, 22*). For example, fatherless students scored in the 55th percentile on the American College Entrance Examination test, while a comparable group from intact homes scored in the 65th percentile (*23*). A recent extensive study of desegregation (*24*) found children from intact homes scoring 100.64 (S.D. 15.05) on a combined mathematical and verbal achievement test, and children from single-parent homes 95.37 (S.D. 13.95)—a difference of one-third of a standard deviation. Other studies show similar effects (*25–29*). Differences in intelligence and in intellectual performance found between children from fatherless homes and from intact homes are greater the longer the father's absence and the younger the child when loss of the parent occurred (*25–27*). Interestingly, the most severe deficits are often in the quantitative skills (*22, 26*). It appears also that, in comparison with other causes of loss of parent, death may have an especially depressing effect on intellectual performance (*30*). Although being deprived of a parent is generally accompanied by stress in the home from other sources, such as marital conflict or bereavement, intellectual deficits occur even when the father's absence is temporary and free from these stressful correlates. Children of men in the service (*26*), for example, and children whose fathers are frequently absent or not readily available because of their occupation, show substantial intellectual and academic lags (*25*). Restoration of adult presence has beneficial effects. Remarriage of the remaining parent, especially if it occurs early in the child's life, results in improved intellectual performance (*30*).

Many of the cited studies did not control for socioeconomic factors such as sharp drops in income due to fathers' absence. But deficits in the intellectual test performance of fatherless children are also found when comparisons are made within a single socioeconomic stratum (*16*). For example, Carlsmith's subjects (*26*) were all Harvard undergraduates whose fathers had been in military service; absence of these fathers would not have caused appreciable drop in income. Santrock (*30*) found similar deficits in samples of white lower-class children.

Table 2. Mean verbal reasoning scores and mean birth weights of twins, by fate of their co-twins. [Data from (*19*)]

Sex	Twins whose co-twins: Were stillborn, or died in first four weeks			Survived		
	N	Verbal reasoning score	Birth weight (kg)	*N*	Verbal reasoning score	Birth weight (kg)
Males	85	98.2	2.34	967	93.9	2.58
Females	63	99.3	2.22	948	96.5	2.45
Both sexes	148	98.7	2.29	1924	95.2	2.52

Only and Last Children

In all four sets of data in Fig. 1 the only child shows a distinct discontinuity with the family size effect; that is, only children score below a level that would be expected if intelligence increased monotonically with decreasing family size. The discontinuity is fairly pronounced. In three out of the four samples, the only children have lower averages than children from families of two, and in the American and the Dutch data lower than from families of three.

A possible explanation may be that only children have fewer opportunities to be teachers. Children with siblings, especially the older children, show their brothers and sisters how to hold a bat or skip rope, help them tie their shoes, explain to them the meanings of new words and rules of new games, warn them about what may get them into trouble, divulge what they may get away with, spot errors and ineptitude and offer critique. One who has to explain something will see from the other's reactions whether the explanation was well understood, and be prompted to improve the explanation, with the consequence that his or her own understanding of the matter is improved. An active participation in an intellective process is decidedly more instructive than a passive participation (*31*). Only children do not usually have the chance to serve as such intellectual resources.

Viewing the only child from this perspective makes him or her seem like a lastborn child rather than an anomalous firstborn, which has been the usual characterization (*32*). The last child also is usually a nonteacher, since he is unlikely to have skills or information that his older siblings might require. It is interesting that the last child, in at least one of the sets of data in Fig. 1, like the only child creates a discontinuity in the observed patterns. The discontinuity of the last child, however, is with respect to the effects of birth order. In the Dutch sample the last child declines more than other children, and this decline occurs in all family sizes. In the Dutch data the discontinuity for the last child is equivalent in magnitude to the discontinuity for the only child (*33*). Altus (*34*) reports Scholastic Aptitude Test data from the University of California at Santa Barbara that also fit the foregoing pattern. In two-child families the decline from the first to the second (that is, last) was 20.1 (over one-sixth of a standard deviation). In three-child families the decline from the first to the second child was only 2.1 SAT points, but from the second to the last child was 21.9 points.

The nonteacher deficit can be counteracted in the case of last children. The last child who is born many years after the birth of the next to the last enters an environment of intellectually more mature children—a condition that may overcome the nonteacher handicap. Recall that in France, where lastborns tended to show an upswing rather than a decline (Fig. 1), intervals for last children were especially long (Fig. 3). Intervals for last children are also longer than for earlier ones in the United States (*12*). Moreover, the teacher role is not entirely closed off to last children, for there must be some occasions when they, too, can serve as resources. For only children the nonteacher handicap cannot be offset or diminished in these ways. The only children should, therefore, produce a consistent discontinuity in the overall family size effect, whereas the discontinuity of the last children in the effect of birth order should be less consistent because of its vulnerability to the effects of spacing. Where the gaps are known to be especially long, as in France, the inordinate drop for the last child disappears (Fig. 1).

If we consider the effects of gaps together with the nonteacher deficit, then the first child represents an interesting case. As was suggested above, a large gap will allow the firstborn to remain in an "undiluted" environment for a longer period of time and hence benefit his or her intellectual development. But during all this time the child must continue to suffer the nonteacher handicap, which may obliterate the favorable effects of an undiluted environment. The trade-off value between the two opposing factors is not known at present. However, since last children have nothing to lose from the postponement of their arrival, they should show greater beneficial effects of large gaps than should first children. Breland (*2*) reports just such findings for the NMSQT sample. In two-child families, firstborns with large gaps scored .18 S.D. unit and those with short gaps .17 S.D. unit above the mean of the entire sample. In these families, however, secondborn children with long age separations scored .12 unit above the mean and those with short gaps only .04 S.D. unit. In three-child families the pattern was similar.

In general, it would be expected, according to the confluence model, that the larger the interval between adjacent siblings the more likely that the birth-order effect would be reversed, so that the younger child might surpass the older in intellectual attainment. Breland's data are based on observations of individuals who come from different families. Other studies on the effects of age gaps also utilize subjects whose siblings' intelligence scores are not known. There are very few such studies and they show conflicting results (*35*). Most informative would be within-family differences in IQ and their relation to differences in age gaps. One report (*36*) that meets this criterion contains intelligence scores of a small number of entire families. The percentages of pairs of adjacent siblings in

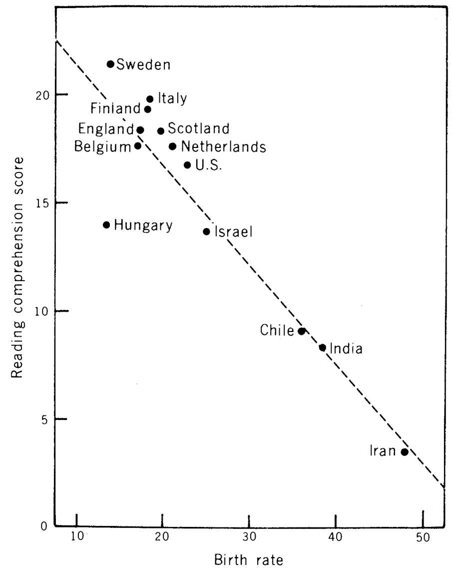


Fig. 4. Reading comprehension scores and birth rates (per 1000 population) in 13 countries (*40*).

which the elder surpassed the younger in IQ were computed in each of four categories of age gaps. These were 59.2, 54.9, 51.6, and 51.1 percent for gaps of 12, 24, 36, and 48 or more months respectively.

National, Regional, Ethnic, and Racial Differences

There are by now a large number of studies reporting differences in intellectual test performance among different national, regional, and ethnic groups. Some investigators have attempted to find genetic explanations but most of these differences have, in fact, gone unexplained. It is clear that these differences share at least one factor: variations in family configuration. Setting aside the important question of whether the various tests used are appropriate measures of intellectual ability in different populations, we may consider whether the national, regional, ethnic, and racial differences in test performance can perhaps be better understood on the basis of differences in family configuration of populations. For example, in 1960 the American white family contained on the average 2.27 children, the American black family 3.05. White and black families also differ in the length of intervals between children. In the white population the average intervals between the first and second child, the second and third, and the third and fourth were 26.7, 31.8, and 30.6 months respectively. The corresponding figures for the black population were 23.1, 23.0, and 22.3. The IQ's of children born to older mothers are consistently higher (*35*). It is interesting, therefore, that the white mother is on the average nearly three years older when she bears her first child than is the black mother. Yet another important aspect of family configuration is the presence of adults in the home; we noted above that the absence of a parent has a depressing effect on intellectual development. Among white Americans, in 1960, 1968, 1970, and 1974 there were respectively 6.1, 7.7, 7.8, and 10.4 percent of households with only the mother present. The comparable figures for black households are 19.8, 27.6, 29.3, and 37.8 (*37*). It would be surprising if these differences in family configuration between whites and blacks were not seriously implicated in the differences sometimes found between these groups in intellectual test performance.

The evidence examined thus far has involved comparisons of intellectual test performance of the individuals' own family patterns. Studies that compare test performance of national or ethnic groups do not as a rule contain family pattern data of their own respondents. However, since they are sampled from populations whose characteristic patterns of family configuration are often known or can be estimated, the association between family factors and intellectual test performance can be examined indirectly. For example, the average IQ's of 5504 children of various ethnic backgrounds in the United States (*38*) have a correlation with family size in the respective ethnic groups that varies between −.49 and −.69, depending on what demographic index is used to estimate family size (*39*). A recent international study obtained measures of reading comprehension for three age groups of school children in a number of countries (*40*). In Fig. 4 reading comprehension scores of one of the age groups (ten-year-olds) is plotted against birthrates in these countries. The intellectual performance scores were obtained in 1971–72; the birthrates are those of 1961–62. The relationship of these scores with the corresponding birthrates is quite strong, and it is nearly as strong in the other age groups.

The French survey referred to earlier (*7*) reports clear differences in IQ among children from different regions of the country. These are paralleled by differences in family configuration. Table 3 shows both the average IQ in each region and another aggregate index of family configuration—average order of births—which combines two important factors of intellectual environment, family size and birth rank. In many countries birth records include information about the mother's previous pregnancies and that information is summarized in demographic yearbooks. Average order of births can be readily calculated from these reports (*41*). High values of average order of births for a given year indicate that children born that year have on the average more older siblings and come from larger families. The association between this index and average IQ is clearly evident.

Table 3. Average order of live births in France in 1962 and average intelligence of French children tested in 1973, by region (*41*).

Region	Mean order of births	Mean IQ	$\frac{X - \bar{X}}{\sigma}$
Picardie-Champagne	3.09	96.5	−.19
Nord	3.08	97.7	−.10
Normandie	3.01	98.7	−.03
Poitou-Centre	2.90	98.1	−.08
Bourgogne-Lorraine	2.86	99.8	.05
Bretagne-Loire	2.82	96.5	−.19
Limousin-Auvergne	2.70	97.5	−.12
Alsace-Strasbourg	2.68	98.6	−.04
Sud-Ouest	2.52	99.1	−.01
Sud-Est	2.42	101.1	.13
Région Parisienne	2.27	102.9	.25

There are, of course, other important differences among groups, regions, and countries besides those in birth rates, order of births, and family size. Differences in economic resources, educational opportunities, linguistic habits, and literacy rates, for example, would contribute to these differences in intellectual performance scores. It is not being argued here that variation in family pattern is the only factor implicated in the intellectual differences.

Sex Differences

The sort of confounding with socioeconomic or genetic factors which obscures the source of the association between family pattern and regional or ethnic differences in intelligence is totally absent with respect to sex differences. In the United States, the Scholastic Aptitude Test scores of males have tended to be somewhat higher on the average than those of females. In the speculation about factors that might account for sex differences in SAT's the possible contribution of family configuration has been thus far overlooked. There are two consistent differences between the positions of males and females in the family configuration. First, the intervals following male births are somewhat longer than those following female births (*42*), probably because of parental preference for male offspring. Second, females are more likely to come late in the sibship than are males (*43*). This difference in the average order of births of the two sexes is quite small, but in the United States, for example, it has occurred without exception for at least the last 28 years. A preference regarding the sex of offspring cannot explain this second difference. There are more fetal deaths among males than among females. Also, fetal deaths are more likely to occur in later pregnancies (*44*). These two factors could combine to produce the consistent sex differences in aggregate birth order.

If sex differences in SAT's are associated with differences in the kinds of family environments that surround males and females, then the magnitudes of sex differences in SAT's should be systematically related to the magnitudes of sex differences in the order of births. In Fig. 5 this association (with both differences expressed in ratios) is shown for years in which SAT data were published by sex. Except in 1957, the relation between the two ratios is quite strong. In the large NMSQT sample (*2*) the pattern is similar: males achieved an average score of 103.45 and females 101.28, a ratio of 1.021. The ratio of birth orders in that sample, female/male, was 1.013. Since the female high school students who take SAT's (or the NMSQT) come from the same populations as the male, economic, regional, or linguistic differences could not have contributed to this relationship.

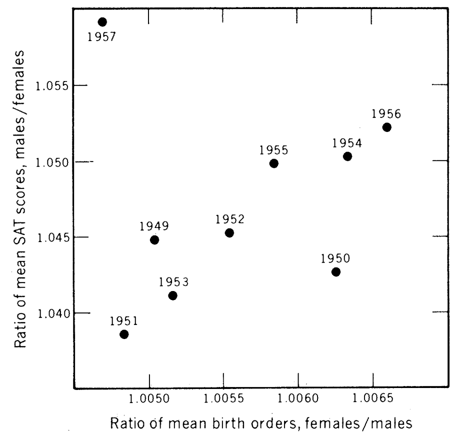


Fig. 5. Differences in mean SAT scores of males and females (expressed in ratios) and their relation to sex differences in average orders of live births (also expressed as ratios).

Trends in Family Configuration

Return now to the marked decline in SAT scores. As with the sex differences, short temporal trends in these scores cannot be attributed to socioeconomic factors, let alone to genetic effects. The proportion of poor and minority students remained fairly stable in the period of declining scores (*1*). Moreover, if the decline in scores were due to increases in the numbers of poor and minority students taking the tests, the main change in the distribution of the scores would be an increase in the proportion of low scorers, without any changes in the absolute numbers of high scorers. That has not been the case. In 1972, for example, there were 53,794 high school seniors with verbal SAT scores of over 650 (two S.D.'s above the mean). In 1973, when the mean verbal score dropped by 8 points, only 39,779 seniors had such scores (*1*).

High school seniors for whom average SAT scores are known were born between 1940 and 1957, and the scores can be compared with the corresponding average birth orders of children born in those years (Fig. 6). Except in the World War II years, the association is close indeed (*45*). During the war years there was considerable fluctuation in birthrate and thus in average orders of births. Also, the proportion taking SAT's was smaller among those cohorts than it is today. But even for the wartime cohorts SAT scores reflect birth order fluctuations to some extent. After 1946 the two trends are virtually parallel. For some recent years the number of high school students with SAT scores above 500 is known. When we compare the percentage of such students with the percentage of firstborns in the respective cohorts (Fig. 7) the correspondence is also quite striking.

As may also be seen in Fig. 6, in 1962 the average birth order begins to rise markedly. Of the 1947 births 42 percent were first children. In 1962 only 27 percent were first children, but the proportion has been steadily increasing, and last year's births include as large a proportion of firstborns as did the 1947 births. Children born in 1963 will be taking the SAT's in 1980. If average orders of births are reliable predictors of SAT scores, in 1980 ± 2 the alarming downward trend should be reversed. This prospect can be partially verified on younger children, for scores on school tests of chidren born around 1963 should begin showing increments now. Temporal changes in test scores of Iowa children born between 1953 and 1967, together with aggregate orders of births in that state, are shown in Fig. 8 (*46*). There is indeed a rise in scholastic performance which begins exactly with the children born in 1962, when birth orders begin to rise. Similar trends are observed among third-, sixth-, and ninth-graders in New

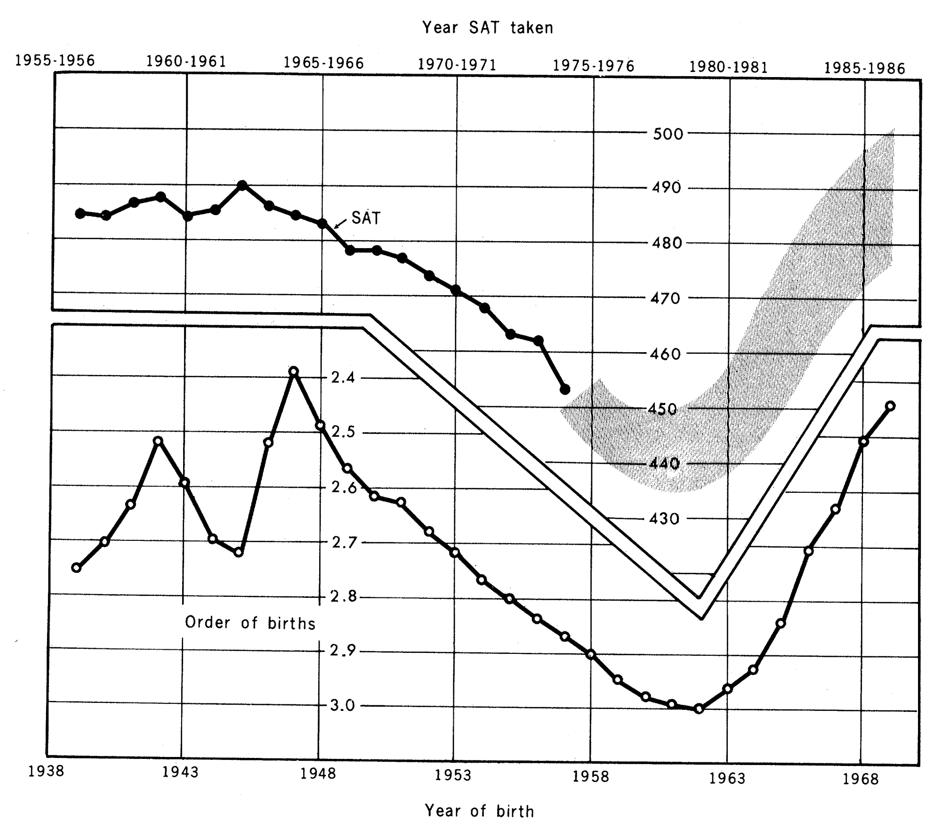
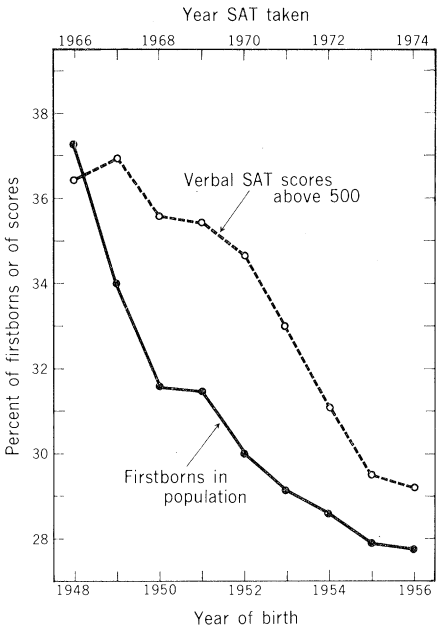
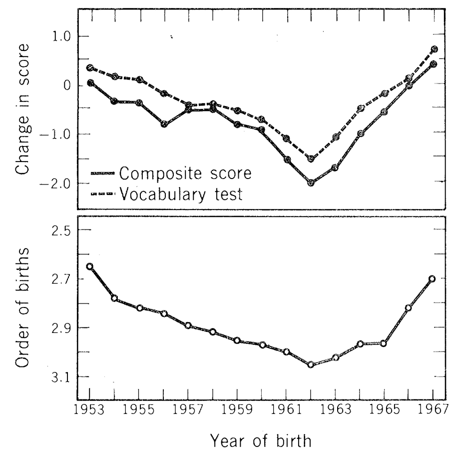


Fig. 6. Average order of live births in the United States, 1939 to 1969, and average SAT scores for the first 18 cohorts. Future SAT averages are predicted to lie within the shaded area.





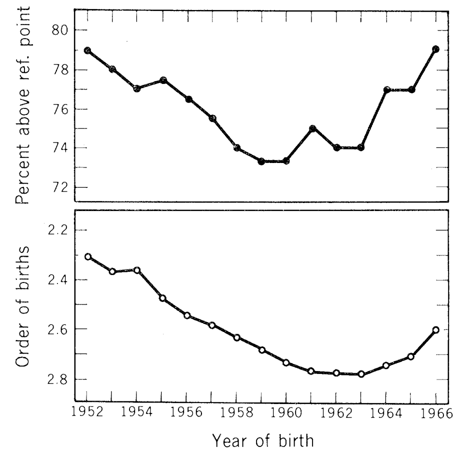


Fig. 7 (left). Percentage of SAT scores above 500, 1966 to 1974, and percentage of firstborns in the corresponding cohorts. Fig. 8 (center). Average order of live births in Iowa, 1953 to 1967, and changes in Iowa Basic Skills scores of these cohorts (grades 3 to 8). In the Iowa Basic Skills Testing Program 1965 was designated as the base year, and all scores are reported as deviations from the 1965 average score (*46*). Fig. 9 (right). Average order of live births in New York State, 1952 to 1966, and percent of third-, sixth-, and ninth-grade pupils who surpassed 1966 reference point in reading skill (*47*).

York State (Fig. 9). That state established a testing program in 1966, at which time a "reference point" was chosen for each of the three grades. The percentages of pupils who surpassed that reference point in reading skills (Fig. 9) parallel the changing average order of live births of the cohorts (*47*). Beginning with children born in 1963 there is a definite rise in test scores which is coincidental with the sharp reversal in birth trends. Several other states have also reported rising test scores recently in lower elementary grades.

Summary and Conclusion

A variety of findings reveal the impact of family configuration on intelligence: (i) Intellectual performance increases with decreasing family size. (ii) Children born early in the sibship perform better on intelligence tests than later children when intervals between successive births are relatively short. (iii) Long inter-sibling spacing appears to cancel the negative effects of birth order and in extreme cases to reverse them. (iv) In general, long intervals enhance intellectual growth. (v) The adverse effects of short intervals are reflected in the typically low IQ's of children of multiple births. (vi) In the special case of only children, the benefits of a small family are apparently counteracted by the lack of opportunities to serve as teachers to younger children. (vii) Last children suffer that handicap too. (viii) Absence of a parent is associated with lower intellectual performance by the children. (ix) Temporal changes in family patterns such as birthrates, average orders of births, intervals between children, and family size are reflected in temporal changes in aggregate measures of intellectual performance. (x) Differences in family patterns between different countries, between different regions of the same country, and between ethnic or racial groups are also associated with differences in aggregate intellectual performance. (xi) Males and females differ in average birth order, and this difference is reflected in aggregate intellectual performance scores.

The pattern of these diverse data is consistent with the analysis of intellectual development based on the confluence model. Of course, not all variation in intelligence is accounted for by variation in family configuration. For example, in the United States the large decline in SAT scores (over ⅓ S.D. in 12 years) cannot be a function of changes in family configuration alone because it is considerably larger than we would expect on the basis of a simple extrapolation from the four national samples in Fig. 1. Nor is all of the sex difference in SAT scores accounted for by the sex difference in orders of births. It should not be overlooked, however, that the average birth orders in these data are based on entire cohorts, whereas SAT's were taken by only 25 percent of the children in these cohorts.

Nor is it claimed that the confluence model generates a unique interpretation of all these facts. For each of them one could probably supply another reasonable explanation. The intellectual deficit of twins could have a biological basis, for example, and the higher intelligence of twins who lost their co-twins may involve unknown genetic factors. The drop in SAT's may be due to a general decline in intellectual interests, and the lower intelligence scores of children living in one-parent homes may be due to a history of conflict or stress. Future research will shed light on these questions. At the moment, however, the confluence model has the advantage of parsimony. And because it makes rather specific predictions, it can be readily verified.

Lest premature implications be drawn from this paper for family planning, education, population growth, or composition of day care centers, another word of caution is called for. IQ isn't everything. Large families may contribute to growth in attributes other than intelligence: social competence, moral responsibility, or ego strength, for example. These or similar family effects are still to be verified, however.

What contribution can the confluence model make to the controversy between the hereditarian and the environmentalist view of intelligence? Clearly, on the basis of the empirical evidence now available, we cannot evaluate the relative importance of the two factors, and the controversy will not be resolved until we know precisely how these factors influence intellectual development. Hereditarians lack information about genetic loci that might transmit intelligence, and environmentalists have not been able to identify the critical features of the environment that generate intellectual effects (*48*). And the two groups suffer equally from ambiguities about what abilities intelligence tests are assumed to measure in different populations (*49*). Generally, the environmental case has relied more on attacking the inadequacies of the genetic position than on positive evidence that would establish the role of environmental factors in intellectual development. Moreover, the hereditarian view has had the advantage of a formal model—the polygenic model of parent-offspring resemblance (*50*)—while up to now there has been no parallel formalization of environmental effects.

Some specific derivations with implications for the analysis of genetic effects on intelligence follow directly from the confluence model. Such analysis utilizes estimates of heritability, some of which involve comparisons between correlations of the intelligence of twins and correlations of the intelligence of nontwin siblings. According to the confluence model, such comparisons must suffer from a confounding with birth intervals. The age gap for twins is, of course, constant at zero, whereas age gaps between other siblings vary. If variations in birth intervals affect the early and the later children differentially (as seems to be the case), heritability indices based on sibling correlations without regard to birth intervals are inaccurate. Similarily, parent-offspring correlations, which are also parts of heritability estimates, are inaccurate if they do not control for birth order, birth intervals, and family size. If there is in fact a close relation between IQ of parents and of children, and if family factors influence the intercept of the corresponding regression line, then combining over birth order and family size simply adds variance around all the points of the regression line and thus attenuates the over-all coefficient. Third, the interpretation of the close intellectual similarity of separated twins may have underestimated the contribution of environmental factors. According to the confluence model, placing twins in two separate environments makes these environments more similar. If two families of the same size adopt twins (or two other individuals who do not differ in mental age), the average intellectual levels of these families will be necessarily more similar after adoption than previously. These effects may be quite small. Nevertheless, in inferences about genetic effects drawn from adoption studies the influence that the foster child may have on the foster family environment should be considered.

While aggregate data support the confluence model in a variety of ways, its full usefulness can only be determined when its predictions are tested against a substantial sample of family configurations, examined repeatedly over a period of several years. From such data the relation of the environmental variables that it specifies to the total IQ variance in the sample can be measured. Since it is sometimes asserted that as much as 86 percent of this variance is genetically determined, it would be of some interest to establish just how much can be assigned to environmental factors when the analysis begins with them. Judging from the consistency and magnitude of some of the effects reviewed here, it would be surprising if the variables specified by the confluence model did not account for more than the small fraction allowed by heritability analysis to environmental factors and to error. When we have calculated the variance in IQ that is associated with the environmental variables of family size, birth rank, birth intervals, parental absence, and presence of other adults in the home, and with the portion of the parent-offspring covariation that has no genetic bases, the interplay of genetic and environmental forces in intellectual performance will be better understood.

References and Notes

1. S. A. McCandless, paper presented at the western regional meeting of the College Entrance Examination Board, San Francisco, 1975.

H. M. Breland, *Child Dev.* **45**, 1011 (1974).

3. R. B. Zajonc and G. B. Markus, *Psychol. Rev.* **82**, 74 (1975).

4. Absolute intellectual level M_t attained by a given child at age t is assumed to develop as a sigmoid function of age. The only child grows according to the function $f(t) = \alpha_1[1 - \exp(-k^2t^2)]$, where α_1, the intellectual environment in the family at birth of the child, is a function of the average of the intellectual levels of all family members including the newborn child, and k is an arbitrary constant that varies with the type of intellectual ability examined or with the scale used for its measurement. The first child of a larger family also grows according to the function $f(t)$ until a sibling is born, at which time the firstborn will shift from $f(t)$ to some other function, $g(t) = \alpha_2[-\exp(-k^2t^2)]$, where α_2 is the new intellectual environment that coincides with the birth of the second child. If there is another child still later, the intellectual growth of the firstborn would change to yet another function, $h(t) = \alpha_3[1 - \exp(-k^2t^2)]$, and so on. If the second child is born when the first is t_1 years old, we can estimate the firstborn's absolute intellectual level M at t_2 from the sum of the two functions $f(t)$ and $g(t)$, where the first is evalulated from age t_0 to age t_1 and the second from t_1 to t_2.

$$M_{12} = f(t)\Big|_{t_0}^{t_1} + g(t)\Big|_{t_1}^{t_2} = \alpha_1[1 - \exp(-k^2t_1^2)] + \alpha_2[1 - \exp(-k^2t_2^2)] - \alpha_2[1 - \exp(-k^2t_1^2)]$$

5. In social and developmental p.. .hology, environmental effects have been generally treated as independent of the individual. Such an approach simplifies analysis, but it is decidedly a misrepresentation of reality. Perhaps when the individual-environment interaction is examined at a fixed point in time an independence of this sort may be assumed. However, when developmental processes and changes over time are involved, specific features of the individual-environment interdependence must be incorporated in the analysis, for if at one time individual A influences the state of individual B, and if later B's state affects the state of A, then A's initial state affects A via changes in B.

Moreover, treating the environment and the individual as independent units not only violates intuitive notions of social reality, it also leads to inaccurate theoretical implications. If the confluence model did not include the individual in calculating his or her own intellectual environment, later-born children would always be predicted to have environments superior to those of earlier-borns. For example, at the birth of the second child the environment of the firstborn would be (30 + 30 + 0)/3 = 20 and of the secondborn (30 + 30 + x)/3 > 20, because x > 0. This advantage of the secondborn would continue throughout the growth process, and a negative birth order effect would invariably be predicted, a theoretical result that is in clear conflict with data in Table 1 and with other results which will be reviewed below.

6. *The Trend of Scottish Intelligence* (Univ. of London Press, London, 1949); the data used in this article were computed from pp. 101–117.

7. *Enquête Nationale sur le Niveau Intellectuel des Enfants d'Age Scolaire* (Institut National d'Etudes Démographiques, Paris, 1973); the data used in this article are from pp. 25–115.

8. Dutch data in this article were recomputed from L. Belmont and F. A. Marolla, *Science* **182**, 1096 (1973).

9. It was conflicting results of this type which prompted some scholars to doubt whether birth order deserves "the heavy investment needed to carry out any more definitive studies" [C. Schooler, *Psychol. Bull.* **78**, 161 (1972)].

10. *Demographic Yearbook* (United Nations Publications, New York, 1954), pp. 252–261; *ibid.* (1965), pp. 276–299. Birthrates are births per 1000 population.

11. J. C. Deville, *Enquête de 1962* (Institut National de la Statistique et des Etudes Economiques, Paris, 1962). The tables were supplied by L. Henry, Institut National d'Etudes Démographiques. Very similar results are reported for 1954 J. Magaud and L. Henry, *Population* **23**, 879 (1968).

12. Bureau of the Census, *Current Population Reports*, Series P-20, No. 108 (Government Printing Office, Washington, D.C., 1961), pp. 46–48.

13. *Mouvement de la Population* (Institut National de la Statistique et des Etudes Economiques, Paris, 1967), p. 260; *ibid.* (1969), pp. 159, 212, 266. The Dutch data were supplied by H. G. Moors and were calculated by G. B. Markus.

14. The quadratic trend is amplified by averaging sigmoid function assumed here to represent intellectual growth.

15. L. Tabah and J. Sutter, *Ann. Hum. Genet.* **19**, 120 (1954).

16. S. H. Broman *et al.*, *Preschool IQ: Prenatal and Early Developmental Correlates* (Erlbaum, Hillsdale, N.J., 1975).

17. H. L. Koch, *Twins and Twin Relations* (Univ. of Chicago Press, Chicago, 1966).

18. R. B. McCall, M. I. Appelbaum, P. S. Hogarty, *Monogr. Soc. Res. Child Dev.* **38**, 1 (19 S. N. Mehrotra and T. Maxwell, *Popul. Stud.* **3**, 295 (1949); L. L. Thurstone and R. L. Jenkins, *J. Educ. Psychol.* **20**, 641 (1929).

19. R. G. Record, T. McKeown, J. H. Edwards, *Ann. Hum. Genet. Soc.* **34**, 11 (1970).

20. Prematurity of birth, which is common in twins, was found by Koch (*17*) to be unrelated to twin intelligence. Premature twins were not lower on any of the intellectual performance measures than full-term twins.

21. H. B. Biller, *Parental Deprivation* (Lexington Books, Toronto, 1974).

22. D. B. Lynn, *The Father: His Role in Child Development* (Brooks-Cole, Monterey, Calif., 1974).

23. B. Sutton-Smith, B. G. Rosenberg, F. Landy, *Child Dev.* **39**, 1213 (1968).

24. H. B. Gerard and N. Miller, *School Desegregation* (Plenum, New York, in press).

25. R. W. Blanchard and H. B. Biller, *Dev. Psychol.* **4**, 301 (1971).

26. L. Carlsmith, *Harv. Educ. Rev.* **34**, 3 (1964).

F. Landy, B. G. Rosenberg, B. Sutton-Smith, *Child Dev.* **40**, 941 (1969).

28. E. E. Lessing, S. W. Zagorin, W. Nelson, *J. Genet. Psychol.* **117**, 181 (1970).

29. Note that the early intellectual environment of twins [(30 + 30 + 0 + 0)/4 = 15] is equivalent to that of the single child in a one-parent home [(30 + 0)/2 = 15]. It is interesting, therefore, and supportive of the confluence model, that the deficits in test scores of twins and of children from one-parent homes are similar in magnitude.

J. W. Santrock, *Child Dev.* **43**, 455 (1972).

31. E. Burnstein, *Psychol. Monogr.* **76**, No. 35 (19 F. I. M. Craik and R. S. Lockhart, *J. Verb. Learn. Verb. Behav.* **11**, 671 (1972); R. B. Zajonc, *J. Abnorm. Soc. Psychol.* **67**, 96 (1960).

32. J. Sadger, *Fortschr. Med.* **29**, 601 (19 S. Schachter, *Am. Sociol. Rev.* **28**, 757 (1963).

33. See (*3*, p. 81). The handicap of the lastborn is represented by a separate parameter λ in the confluence model (*3*, p. 86).

34. W. D. Altus, *J. Consult. Psychol.* **29**, 202 (1965).

V. G. Cicirelli, *Child Dev.* **38**, 481 (1967); B. G. Rosenberg and B. Sutton-Smith, *Dev. Psychol.* **1**, 661 (1969). A factor that complicates the effects of birth intervals is mother's age at birth of child. Intelligence scores show an increase with maternal age (*16*) that is independent of the ef-

fects of birth order [R. G. Record, T. McKeown, J. H. Edwards, *Ann. Hum. Genet.* **33**, 61 (1969)]. The relation between the effects of mother's age and birth interval, however, remains to be determined.
36. M. C. Outhit, *Arch. Psychol.* **149**, 1 (1933).
37. R. Farley and A. Hermalin, *Am. Sociol. Rev.* **36**, 1 (1971). Data for 1970 and 1974 are from an unpublished study by the same authors.
38. N. D. M. Hirsch, *Genet. Psychol. Monogr.* **1**, 231 (1926).
39. Family sizes were computed from *16th Census of the United States* (Government Printing Office, Washington, D.C., 1940), pp. 127–128, 135–136.
40. Data on reading comprehension are from R. L. Thorndike, *Reading Comprehension Education in Fifteen Countries* (Wiley, New York, 1973), birth rates from *Demographic Yearbook*, (United Nations Publications, New York, 1962 to 1964). The data were plotted against birth rates rather than against average orders of births because the latter figures were not available for three of the countries.
41. Order of live births was computed from *Mouvement de la Population* (Institut National de la Statistique et des Etudes Economiques, Paris, 1969, pp. 535–536. Average order of live births is

$$\Sigma(B_i i)/\Sigma B_i$$

where B_i is the number of live births of the order i. Eighth and later births were combined letting $(i \geqq 8) = 10$.
42. M. P. Schutzenberger, *Sem. Hôp. Paris* **26**, 4458 (1950); G. Wyshak, *J. Biosoc. Sci.* **1**, 337 (1969).
43. M. S. Teitelbaum, *J. Biosoc. Sci.* **2**, Suppl., 61 (1970).
44. J. N. Norris and J. A. Heady, *Lancet* **268** (1955).
45. Birthrates show very similar relationships with SAT trends. For example, the correlation of SAT scores with crude birthrate (births per 1000 population) over the last 18 years is −.61 and with fertility (births per 1000 women of childbearing age) −.71. Minnesota collects scholastic aptitude tests from high school juniors. Over the last 13 years the association between those scores and birth orders in the state was equally high. The scores are in E. O. Swanson, *Student Counseling Bureau Reviews*, vol. 25 (Student Counseling Bureau, University of Minnesota, Minneapolis, 1973), pp. 69–72. The average orders of live births in Minnesota come from *Vital Statistics of the United States*, 1943 to 1955 (Bureau of the Census, Washington, D.C., 1945, 1946; Government Printing Office, Washington, D.C., 1947 to 1957).
46. These figures were computed from data supplied by W. E. Coffman, Director, Iowa Testing Programs. The figures supplied for 1973 and 1974 had been interpolated from 1972 and 1975. Orders of live births for Iowa were computed from *Vital Statistics of the United States*, 1953 to 1964 (Government Printing Office, Washington, D.C., 1955 to 1966).
47. These figures were averaged from data supplied by V. A. Taber, Director, Division of Educational Testing, State University of New York, Albany.
48. L. Erlenmeyer-Kimling and L. F. Jarvik, *Science* **142**, 1477 (1963); J. Hirsch, *Educ. Theory* **25**, 3 (1975); C. Jencks *et al.*, *Inequality: A Reassessment of the Effects of Family and Schooling in America* (Basic Books, New York, 1972); A. R. Jensen, *Harv. Educ. Rev.* **39**, 1 (1969); D. Layzer, *Science* **183**, 1259 (1974); J. A. Rondal, *Psychol. Belg.* **14**, 149 (1974); S. Scarr-Salapatek, *Science* **174**, 1285 (19 P. Urbach, *Brit. J. Phil. Sci.* **25**, 99 (1974).
49. T. A. Cleary, L. G. Humphreys, S. A. Kendrick, A. Wesman, *Am. Psychol.* **30**, 15 (1975); L. J. Cronbach, *ibid.*, p. 1; D. Wechsler, *ibid.*, p. 135.
50. C. Burt, *Brit. J. Psychol.* **57**, 137 (1966).
51. This research was supported by grant 1-R01 HD08986-01 from the National Institute of Child Health and Human Development. This paper was completed while I held a fellowship at the Center for Advanced Study in the Behavioral Sciences. I am grateful to Patricia B. Gurin, Gregory B. Markus, Richard E. Nisbett, Howard Schuman, Beth Shinn, and especially Hazel J. Markus for their helpful comments and critique. I also thank Benno G. Fricke, Harold B. Gerard, Albert A. Hermalin, Louis Henry, Sam McCandless, Hein G. Moors, and E. W. Swanson for allowing me to have data they collected and for directing me to important sources of other data, and to Louis Gottfried, David Reames, and David Ravid for their assistance in tabulating some of the results reported here.

NEWS AND COMMENT

Recombinant DNA: The Last Look Before the Leap

The tortuous and possibly historic debate on whether to proceed with research on recombinant DNA is now nearing the end of its first round, with a clear victory in sight for those who wish research to go ahead under stiff but not grossly inconvenient safety conditions.

This is the course that is favored by probably a vast majority of biological researchers. Yet it is worth noting the strong dissent of two scientists who are as eminent as any of the contributors to the debate, and who in addition have no personal interest in using the technique. Robert Sinsheimer, chairman of the biology division at Caltech, believes that all research should be confined to one site, such as the former biological warfare laboratories at Fort Detrick. Erwin Chargaff of Columbia University would like to see the research prohibited altogether to allow a two-year period of "cooling off" and reflection.

These views occur in written comments solicited by National Institutes of Health director Donald S. Fredrickson. On the basis of the comments, and of the record of a public hearing on the issue (*Science*, 27 February 1976), Fredrickson has proposed some minor emendations to the present draft guidelines on recombinant DNA research prepared by an NIH committee. At a two-day meeting held on the NIH campus last week, the same committee considered and rejected most of them.

Whether or not Fredrickson accepts the committee's advice, the guidelines that he will issue within the next few weeks will not differ greatly from the present draft.

It is perhaps a pity that Sinsheimer's views were not discussed by the NIH committee last week because, though not widely held, they are by no means negligible. Moreover, Sinsheimer seems to have a broader sense of perspective than others about the place of the new technique both in history and in evolution. His critique of the guidelines is premised on a fundamental and so far unrefuted theorem, that there is a barrier to genetic exchange between the two great classes of living things, the prokaryotes and the eukaryotes. (Prokaryotes are primitive cells, such as bacteria and blue-green algae, which lack a nuclear membrane; eukaryotes, the cells of all higher organisms, have a quite different and more sophisticated organization.)

Many of the proposed experiments with recombinant DNA involve inserting segments of eukaryotic DNA into prokaryotic cells, and the whole thrust of the guidelines has been to rank these experiments in a graded series of risks based on the nature of the eukaryotic DNA segment. Sinsheimer, however, believes that the risk lies not in the particular DNA being inserted, but in the very fact of putting eukaryotic genes into prokaryotes. If he is right, the elaborate edifice of rules constructed by the NIH committee is built on a foundation of sand.

Sinsheimer's argument, as expressed in two letters sent to Fredrickson in February, goes as follows.

Though prokaryotes and eukaryotes interact intensely with each other as organisms, they are not known to interact with any frequency at the genetic level. One evident reason for this lack of genetic intercourse is that, though they use the same genetic code, they have different control elements, different genetic signals for governing how the code is to be put into operation. The great danger of putting any piece of eukaryotic DNA into a prokaryote is that it may endow prokaryotes with the eukaryote control signals, a sort of betrayal of state secrets at the molecular level. Even if this occasionally happens by accident in nature, Sinsheimer says, numerous experiments of the type envisaged can only increase the risk.

What might be the consequences of breaching the natural barrier between prokaryotes and eukaryotes? One is that the prokaryotic viruses, particularly the lysogenic species, could acquire the capacity to infect eukaryotes. A bacterial virus carrying the gene for a restriction enzyme, for example, could wreak havoc inside a eukaryotic cell. Another pos-