flash, a function similar to the homochromatic cone function is obtained, except that it shifts to the right, peaking at a much longer time interval. With the 420-nm test flash and a 680-nm conditioning flash, the function shifts to the left of the homochromatic "rod" function, peaking at negative time intervals. In summary then, any of the four wavelength combinations result in significant deviations from the RT condition. To the extent that 420-nm stimuli indeed affect rods and 680-nm stimuli affect cones, the data thus suggest rod-cone interaction.

We might attempt to account for the data in terms of rod-cone independence by assuming that all flashes stimulate both classes of receptors, but that the 680-nm stimuli have a stronger effect upon cones, the 420-nm stimuli upon rods. It would be expected, accordingly, that homochromatic conditions would result in the greatest similarity between receptor populations stimulated by test and conditioning flash and thus would result in the greatest threshold changes. The data are not consonant with such an argument because the primary effect of conditioning wavelength is on the time course and not the magnitude of threshold change (*11*). In consideration of physiological evidence indicating that the rod system has a longer latency than the cone system (*2*), this time shift suggests rod-cone *interaction,* not independence. Let us assume in the present situation that for a fixed wavelength test flash, an interaction between test and conditioning flashes occurs with a definite time course. It would be expected that a cone conditioning flash would produce its effect earlier in time than a rod conditioning flash because of the shorter latency of the cone system. The data in Figs. 1 and 2 are very much in agreement with this conclusion, as are the electrophysiological data obtained at the ganglion cell level (*2*). Whether this interaction between rod and cone stimuli occurs just at the ganglion cell level or at multiple sites within the primate visual system, however, can only be determined by further electrophysiological investigation.

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9. With 420-nm stimuli, all flashes appeared colorless, were within the rod limb of a long-term dark-adaptation curve, and had much higher thresholds in the foveal than at 7°. With 680-nm stimuli, all flashes appeared red, no rod function was evident with long-term dark adaptation, and the flashes had appreciably lower thresholds in the fovea than at 7°. Increment threshold functions obtained according to the method of W. S. Stiles [*Doc. Ophthalmol.* **3**, 138 (1949)] indicated that within 1 log unit of threshold, 420- and 680-nm stimuli were affecting different receptor populations. With similar adaptation conditions and parafoveal stimulation, Westheimer (*6*) has noted a Stiles-Crawford effect with long wavelength but not with short wavelength stimuli.
10. No measurable long-term light adaptation was produced by conditioning flash stimulation with this recyling rate.
11. We might similarly attempt to account for our data in terms of an interaction between blue cones and red cones. Under situations where rod functioning does not exist (foveal photopic stimulation), an interaction between blue and red monochromatic stimuli has been demonstrated by W. R. Bush [*J. Opt. Soc. Amer.* **45**, 1047 (1955)] and E. J. Rinalducci [*ibid.* **57**, 1270 (1967)]. However, temporal displacements of the sort observed in Figs. 1 and 2 were not observed by these investigators.
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Twins: Early Mental Development

Abstract. *Mental development was appraised periodically for infant twins, and the twins displayed high within-pair concordance for level of mental development during the first and second years. Twins were also concordant for the spurts and lags in development in this period (monozygotic twins more so than dizygotic). From these results it was inferred that infant mental development was primarily determined by the twins' genetic blueprint and that, except in unusual cases, other factors served mainly a supportive function.*

For several years the Louisville Twin Study has recruited newborn twins for participation in a longitudinal study of growth and development. The twins are seen at 3, 6, 9, 12, 18, and 24 months of age, and at each age they are tested with the research version of the Bayley scales of mental and motor development. This report gives the results for the mental scale for 261 pairs of twins (*1*).

Infant mental development is a matter of particular interest in its own right. Infant test scores are essentially unrelated to adult intelligence except in cases of marked retardation, and in fact the correlations are relatively low between tests given at 6-month intervals during early childhood (*2*).

The interpretation of these results is that the functions measured during infancy undergo rapid changes as new capabilities emerge and become fully developed. But the rate of gain is not uniform for all children, and consequently for any particular infant there may be significant changes in relative maturity from one age to the next.

At this point, the test data for twins take on added significance. If the emergence of mental functions depends upon genetically determined growth processes, then the level of mental development attained at each age should be comparable for twins. Further, if these processes alternate between phases of accelerated growth and of drift, then the rate of gain between ages for both twins should be subject to the same spurts and lags. Finally, if gene segregation is a significant factor, then the exact duplication of genotypes for identical twins should make them more concordant than fraternal twins.

The Bayley scale was administered within 1 week of the twins' birthday for ages 3, 6, 9, and 12 months, and within 2 weeks for ages 18 and 24 months. The total sample included 225 white same-sex pairs and 36 white opposite-sex pairs. The number of valid tests actually obtained at each age was affected by missed visits due to illness, occasional substitution of other tests, and so forth, so the sample size is reported separately for each analysis. The mean scores and standard deviations for twins are given in Table 1, along with the comparable singleton means at each age as reported by Bayley (*3*).

Table 1. Means and standard deviations (SD's) of Bayley mental scale scores for twins.

Age (months)	Twin		Bayley singleton means	Number of pairs		Within-pair correlations (r)	
	Means*	SD's		MZ	DZ	MZ	DZ
3	33.0	6.08	33.6	71	79	.84‡	.67
6	65.0	7.77	69.6†	85	98	.82	.74
9	83.6	4.51	84.3	82	101	.81‡	.69
12	97.2	5.73	99.6†	86	104	.82‡	.61
18	121.8	6.05	125.0†	88	91	.76	.72
24	141.4	8.62	143.0	57	77	.87‡	.75

* $N \geqslant 400$ through 18 months; $N = 298$ at 24 months. † Singleton mean significantly higher than twin mean ($P < .05$). ‡ MZ correlation significantly higher than DZ correlation ($P < .05$).

The results show that the average score for twins was somewhat lower at each age (significantly so at 6, 12, and 18 months), but the size of the difference was comparatively small. With a modest allowance made for prematurity, it appears that the developmental processes tapped by the Bayley mental scale unfold at essentially the same rate for twins as for singletons.

A separate analysis for sex differences revealed a slight but inconsequential advantage for females at all ages; the difference was significant only at 18 months. In line with Bayley's results, the present data support the view of sex equivalence in performance on the mental scale.

All twin scores were then transformed into standardized developmental quotients for each age, with a mean of 100 and standard deviation of 16. Subsequent analyses were performed with these standardized scores.

To verify the previous reports of low order correlations during infancy, I computed intercorrelations between the individual test scores obtained at each age, and the resulting coefficients ranged from .53 to .08. They were highest for adjacent ages (typically $r > .40$), but even the largest between-age correlation accounted for less than 30 percent of the variance and was well below the estimated reliability of the scale at each age ($r = .88$ to $.94$).

Since the low order correlations cannot be attributed to poor test reliability, they may be reflecting the influence of some systematic factor or factors, perhaps genetic in origin, that modulated the rate of gain in mental development from one age to the next. For example, an infant that was precocious at 6 months of age may have made a relatively slow gain over the next 6 months, and consequently by his first birthday he may have fallen behind the average child. Other infants would be subject to their own idiosyncratic rates of gain; and as a result, changes in relative precocity would be the rule, not the exception, for mental development during infancy.

This interpretation would be considerably strengthened by data showing that two infants that shared the same genetic blueprint actually followed the same course of mental development. Accordingly, the sample was separated into monozygotic (MZ) and dizygotic (DZ) pairs, on the basis of blood-typing tests for 22 or more antigens (*4*). All same-sex pairs that were discordant for one or more antisera tests were classified as DZ and combined with the opposite-sex pairs to form the entire DZ sample. The remaining concordant pairs constituted the MZ sample. For technical and psychological reasons the blood-typing is deferred until the twins are 3 years old, so there are some pairs for whom zygosity has not yet been established. These pairs are omitted from the current analysis.

The expectation was that DZ pairs would show a moderate degree of concordance in mental development by virtue of originating from the same gene pool and growing up in the same family, whereas MZ pairs would be significantly more concordant because all genes were held in common. The analysis was made by computing intraclass (within-pair) correlations for the test scores at each age, and the results are presented separately for MZ and DZ twins in the final columns of Table 1.

The results show that the MZ correlations were significantly higher at most ages and in fact approached the limits set by the reliability of the scale. The duplication of genotypes for MZ twins appears to have had a profound influence on the course of mental development. Further, even the within-pair correlations for DZ twins were higher than the between-age correlations reported earlier, so it is evident that twin A was a better predictor of twin B's score at the same age than he was of his own score at an adjacent age. The short-term developmental changes during infancy produced greater age-to-age deviations for one child than the accumulated differences in biological makeup and experience produced within the average DZ pair.

If the members of a twin pair resembled one another at each age, the next question was whether they followed the same pattern of mental development across ages, with correlated spurts and lags. The score profiles for several sets of MZ twins are presented in Fig. 1; these profiles were selected to illustrate the high degree of congruence that may be found among

Table 2. Analysis of Bayley mental scale scores for twins in first and second years. The within-pair correlation is given by $R = (MS_b - MS_w)/(MS_b + MS_w)$, where MS_b is the mean square between pairs and MS_w is the mean square within pairs.

Source of variance	Within-pair correlations (R)	Test for MZ > DZ (P)	Range of 98 percent level of confidence	Mean square		Degrees of freedom
				Between pairs	Within pairs	
			Ages 3, 6, 9, and 12 months			
Overall level						
MZ pairs	.90	< .01	.80 – .95	645.5	35.6	44/45
DZ pairs	.75		.57 – .86	871.8	122.4	50/51
Profile contour						
MZ pairs	.75	< .01	.65 – .83	280.0	39.1	132/135
DZ pairs	.50		.34 – .63	228.5	76.0	150/153
			Ages 12, 18, and 24 months			
Overall level						
MZ pairs	.89	< .05	.79 – .94	677.8	40.7	50/51
DZ pairs	.79		.62 – .89	614.5	71.0	45/46
Profile contour						
MZ pairs	.67	< .05	.53 – .78	272.4	53.1	100/102
DZ pairs	.52		.33 – .68	200.7	62.4	90/92

twins who follow quite different trends in mental development during infancy.

As the curves show, the score profile for each twin may be distinguished both in terms of contour and overall elevation. The profile contour is a function of age-to-age changes in precocity —the spurt-lag factor—while the overall elevation reflects a more enduring degree of developmental maturity (or immaturity) which persists across several ages. From an analytic standpoint, it would be informative to compute the within-pair concordance for twins on both of these aspects of infant mental development.

The analysis of the test scores was performed separately for each zygosity group by a repeated-measures analysis of variance that was adapted for use with twin data (*5*). The test scores obtained within the first and second years were analyzed separately to determine whether the degree of concordance remained the same for both years, or whether there was some notable change linked to age and zygosity (*6*). The results are presented in Table 2.

When the correlations for overall developmental level are examined, it is evident that the MZ pairs displayed a very high level of concordance within each year; that is, if the cumulative score for one twin were known, the corresponding score for his co-twin could be predicted with a small margin of error. If these correlations for overall level are compared with the MZ correlations in Table 1, it is clear that combining scores across ages minimized the errors of measurement and yielded a within-pair correlation that equaled the estimated reliability of the scale. In fact, the MZ correlations might be said to represent the purest measure of reliability for the developmental scale, since they are based on scores from two genetically identical infants who were raised in the same home and tested at the same age.

There was also a substantial degree of concordance within DZ pairs for overall developmental level, the implications of which are discussed later; but nevertheless the MZ correlations significantly exceeded the DZ correlations in both years. And when the profile contour correlations were examined, it was evident that the MZ correlations were significantly larger than the DZ correlations for this aspect of mental development as well. Since profile contour represents the age-to-age changes in relative precocity, these correlations signify that MZ twins were more closely aligned for the spurts and lags in development.

This analysis suggests that MZ twins and DZ twins constitute two significantly different subpopulations as far as concordance in early mental development is concerned. If the difference is real and large enough to take seriously, the obtained within-pair correlations for MZ twins should fall outside the expected range for DZ twins, and the reverse should also be true. The ranges as set by the 98 percent confidence level are shown in Table 2 for all correlations, and the expectation is met—the MZ correlations are at least as large as the upper 1 percent limit for the DZ range, and conversely the DZ correlations fall below the lower 1 percent limit for the MZ range. So the difference in concordance level between MZ and DZ twins appears to be a stable feature of early mental development which is evident in the first year and maintained throughout the second.

The results clearly reveal a significant genetic influence on both aspects of infant mental development. They confirm the interpretation offered earlier that the age-to-age changes in relative

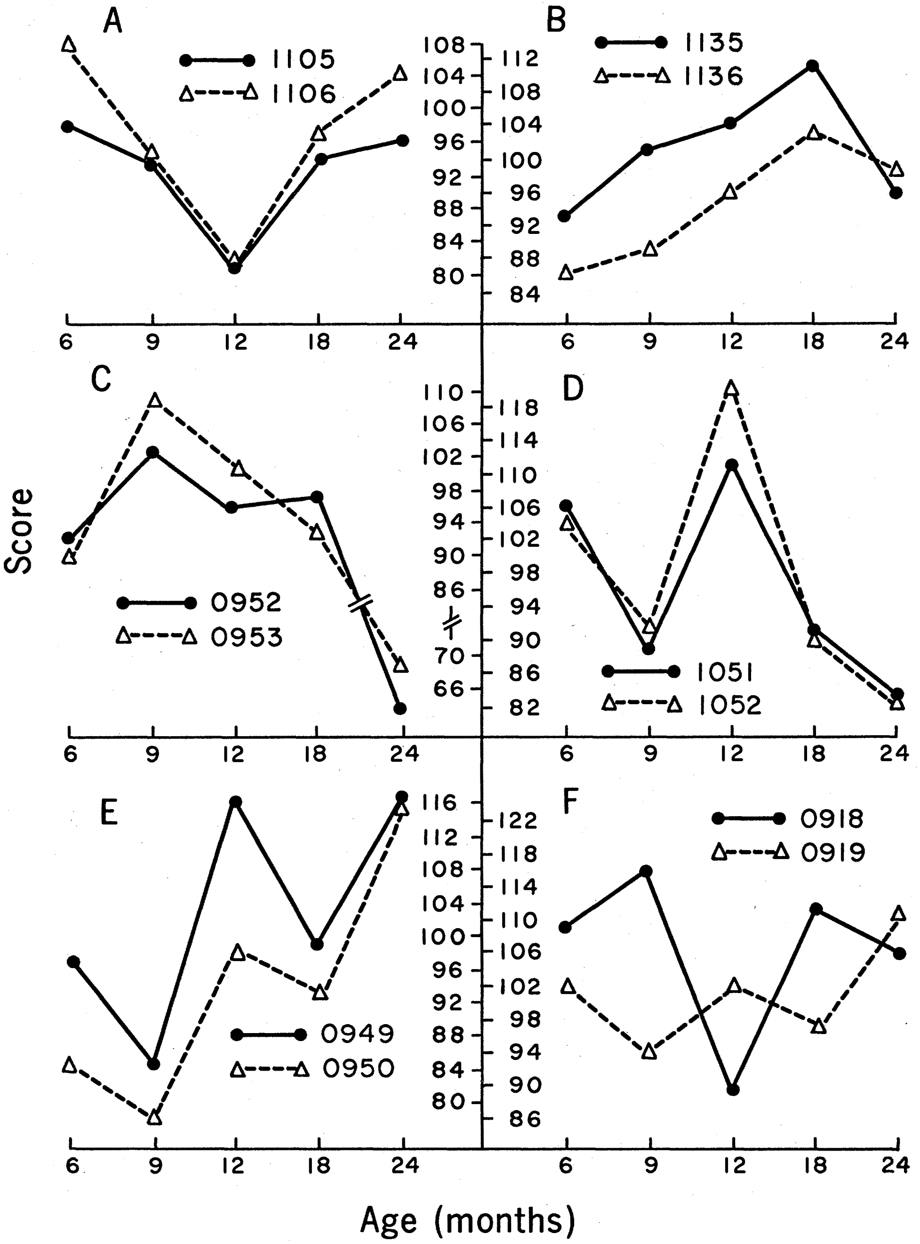

Fig. 1. Profiles of mental development scores for MZ twins at ages 6 through 24 months. The pairs in A to E exhibit moderate to high profile congruence; the pair in F is obviously noncongruent.

precocity are conditioned by genetic factors; and the manner in which these genetic factors exert their age-linked influence presumably follows the pattern that Thompson and Grusec described (*7*): "Thus the expression of certain genes may be so timed that certain types of behavior and certain capacities for discrimination and for articulated response will emerge at particular times." Further, while this conclusion is limited to the infancy period by the present data, we believe that the rate of gain throughout the preschool years will also be found to depend upon genetic factors.

Besides the significantly higher level of concordance for MZ twins, another equally important feature of the twin data is the relatively high degree of concordance for overall developmental level in DZ twins. It signifies that the differences within DZ pairs produced by gene segregation and different life experiences are comparatively small in relation to the sizable differences between pairs. What inference about the role of genetic and environmental factors might be drawn from these results?

The primary source of genetic variance in any nonrandom mating system is between families (technically, between parental mating combinations); and in a nuclear family society, the primary source of environmental variance is also between families. The reference behavior exhibited by offspring from each family is jointly affected by both sources of variance, but the proportion of influence from each source is not necessarily equal.

The influence of home environment will be considered first. The families in this study range from the welfare case to the wealthy professional family, and each family was assigned a socioeconomic status score (SES) by the classification system of Reiss (*8*). When the correlation was computed between SES scores and overall level of development for each year, the relation was very weak for the first year ($r = .11$) and improved only slightly for the second year ($r = .20$). Comparable results were reported by Bayley for her large norm sample (*3*); and taken on balance, both sources of data argue against a significant linkage between precocity of infant mental development and the socioeconomic quality of the home.

Stated more broadly, the conclusion is that the caretaking and stimulation needed to support infant mental development are sufficiently supplied by most home environments that fall above the level of impoverished. In all likelihood, however, there may be a cumulative latent influence absorbed from the home environment during infancy that combines with genetic predisposition and gradually becomes manifest as school age approaches; since the child's measured IQ becomes increasingly related to his parents' IQ, educational level, and socioeconomic status as he gets older (*9*).

Aside from these variables, there are other dimensions of the parent-child relationship that do have some immediate influence upon infant mental development, notably maternal love and acceptance as opposed to hostility and rejection (*10*). The effects of these maternal behaviors are inconsistent by age and sex, however; females develop more precociously during infancy under the shelter of a warm maternal attitude but lose their advantage by school age, whereas the opposite is true for males. A satisfactory explanation is still awaited for these sex differences in response to maternal care; and in any event, the demonstrable relation between maternal care and infant mental development is modest in size and falls below the concordance level for twins.

Therefore, the hypothesis is proposed that these socioeconomic and maternal care variables serve to modulate the primary determinant of developmental capability, namely, the genetic blueprint supplied by the parents. On this view, the differences between twin pairs and the similarities within twin pairs in the course of infant mental development are primarily a function of the shared genetic blueprint.

Further, while there is a continuing interaction between the genetically determined gradient of development and the life circumstances under which each pair of twins is born and raised, it requires unusual environmental conditions to impose a major deflection upon the gradient of infant development. For example, there will be some pairs where development of one or both twins is suppressed by serious prematurity or an impoverished environment; and there will be some pairs where the twins become discordant because of deviant prenatal conditions, birth trauma, or sharply differentiated life experiences. But for the great majority of pairs, life circumstances fall within the broad limits of sufficiency that permit the genetic blueprint to control the course of infant mental development.

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6. Another reason for performing a separate analysis for each year is that the analysis requires test scores from both members of the pair at all ages, so if any score is missing, the pair is excluded. The sample shrinkage in each zygosity group due to exclusions is within tolerable limits for the set of scores obtained within each year, but it becomes prohibitive when the entire age range is covered.
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Age, Location, and Stability of Ecosystems

In their examination of the relationship between the "age" and stability of ecosystems, Hurd *et al.* (*1*) used unreplicated fields of two ages, thereby confounding age with location. Two factors suggest that this confounding is significant. First, *Poa compressa* and *Hieracium pratense*, species characteristic of impoverished sites, are important only in the less productive field, even though both could be expected to be prominent in either field on the basis of age alone;