TWIN RESEARCH 4

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INTRODUCTION

The study of developmental processes in twins furnishes a powerful resource for examining the role of gene-action systems in guiding the course of growth [2,9].

While there is a steady and rapid progression from birth onward, the growth rate is not entirely uniform for a given child, but rather moves in episodes of acceleration and lag. The timing of the growth spurts follows a distinctive pattern for each child, and consequently a child who may be smaller than average at one age may then enter a phase of rapid growth, and ultimately catch up with or surpass his peers at a later age.

The effect of such individualized patterns of growth is that many children may change in relative size from one age to the next; and in this sense it may appear that the underlying developmental processes are erratic, rather than coherent. But if there is an underlying ground plan, a chronogenetic pattern, then the distinctive developmental gradients should unfold in synchrony for twins sharing the same genetic make-up. Episodes of acceleration and lag in growth would then occur in parallel for both twins and would presumably represent the activity of timed gene-action systems, which switch on and off according to a predetermined plan.

Physical growth data are valuable for illustrating these synchronized developmental gradients in twins, since the relationship to genetic factors is well established and the measures themselves are precise and virtually free of error. For psychological data, however, the measures are much less precise, and this has often confounded efforts to demonstrate any continuity in behavioral development during childhood.

In a preceding paper [9], measures of physical growth (height) and mental development were reported for a sample of 67 MZ twin pairs. The twins were measured at 3, 6, 12, 18 and 24 months of age, and the growth curves showed a strong degree of similarity within MZ pairs. For height, the concordance in developmental trend accounted for 82% of the variance over these ages, while for mental development the equivalent figure was 70.7%. Age-to-age changes, or spurts and lags, were more prominent in the mental development data, and these MZ twins displayed a significant linkage for spurts and lags ($R_{MZ} = 0.56$). Overall, height appeared to be more tightly regulated by the genotype than mental development, but the latter showed a surprising degree of synchronization in developmental trends for MZ twins.

The present study expands upon these results in two directions: *(a)* DZ twins are included for comparison with MZ twins, and *(b)* the age range is extended to 6 years. Previous results have shown that the spurts and lags in mental development are considerably smoothed by 6 years – the measures of intelligence become more stabilized, and age-to-age consistency is steadily increased [10]. As this stabilization occurs, the question may be posed whether the measures of MZ and DZ concordance show any changes over this age period. And do the measures of height show the same concordance patterns as mental development? Finally, one may inquire whether the growth gradients for height and mental development proceed in yoked fashion, or unfold independently.

The twins were part of a larger longitudinal study in which measures of height and mental development were routinely obtained throughout childhood [for a description of the sample and the assessment procedures, cf Wilson 1983].The data to be analyzed were obtained when the twins were 1½, 2, 3, 4, 5 and 6 years old. The Bayley Mental Scale was administered at 1½ and 2 years, the Stanford-Binet at 3 years [5], the McCarthy Scale at age 4 [4], and the Wechsler Preschool and Primary Scale of Intelligence at ages 5 and 6 [6]. The twins were tested by separate examiners at each visit, who also alternated between the twins over successive visits.

Each test yielded age-adjusted standardized scores with a mean of 100; and for comparison purposes the height measures were also standardized at each age, using the complete twin sample as the standardization group ($n > 600$). An infant of average height at every age would have scores of 100, with no variability.

But if there were episodes of acceleration or lag in growth, the standardized scores would change across ages, reflecting the relative upward (or downward) shift of the child's height in relation to his age mates. Similarly, the profile of mental development scores would reflect phases of rapid advancement or lag in the growth of mental functions, as measured by the mental tests.

The basic data may be illustrated by reference to the growth curves for two MZ and two DZ pairs, as shown in Figs. 1 and 2. For brevity, the mental development curves are designated as IQ and the height curves as HQ.

In Fig. 1, there was a substantial amount of age-to-age change in the IQ scores, reflecting spurts and lags in development, but both MZ twins exhibited the changes in parallel. The changes were much smaller for HQ, although again the twins closely tracked one another. The extent of similarity within each pair can be expressed by a developmental synchronies index (DSI), which ranged from 0.81 to 0.97 for these MZ twins[1].

The DZ pairs in Fig. 2 showed somewhat less synchronized trends, especially for HQ, although in only one case was there a progressive divergence over age. It is worth noting in the upper left and lower right graphs that the curves tended to move in parallel over age, although there was a sizable difference in average score between the curves. This difference is reflected in the DSI values of 0.61 and 0.53, which would otherwise be much higher if the curve elevations were equal. DZ pairs may thus be discordant for the profile of the growth curve or for its average value, but both factors are jointly considered in the developmental synchronies index.

CONCORDANCE AT EACH AGE

Turning to the full sample, we initially computed the within-pair correlations at each age for MZ and DZ twins, to determine whether there were progressive changes in concordance over age. For perspective, the correlations were extended back to 3 months for mental development, and to birth for height. The results are presented graphically in Fig. 3.

The results showed that MZ twins were less concordant for height at birth than DZ

[1] The developmental synchronies index is derived from the variance components that jointly express the degree of concordance for overall score profile, taking into account both the elevation and the patterning of the scores. The variance components are drawn from a repeated-measures analysis of variance for twins [8], but instead of averaging over pairs, the disparities in score profile are computed and held separately for each pair. These deviation scores are then processed through the equation for within-pair (intraclass) correlations, and the resultant figure expresses the developmental synchronies index for each pair. The closer this figure comes to 1.00, the smaller the disparity and the closer the fit in the curves.

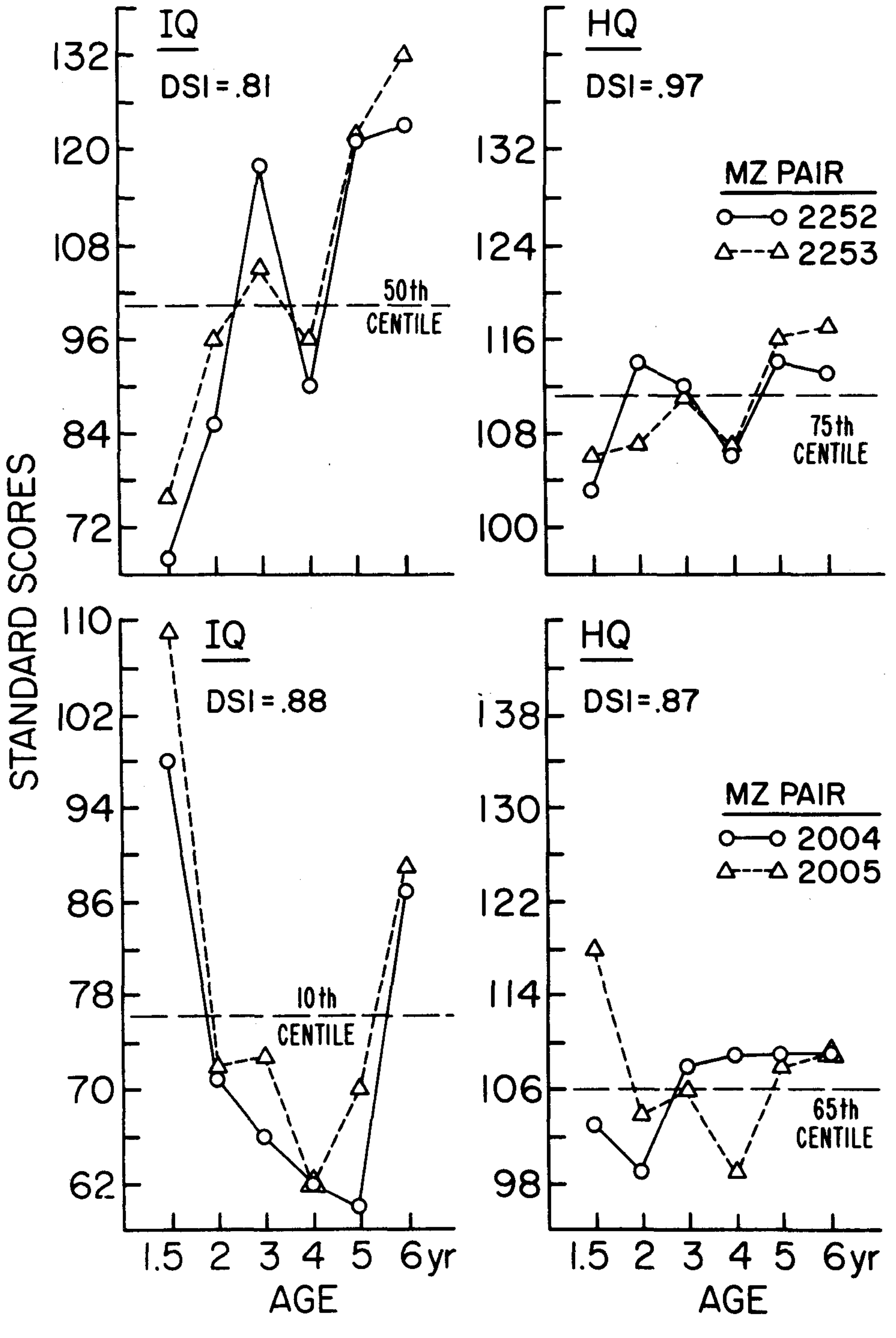

Fig. 1 - Growth curves for height (HQ) and mental development (IQ) for two MZ pairs.

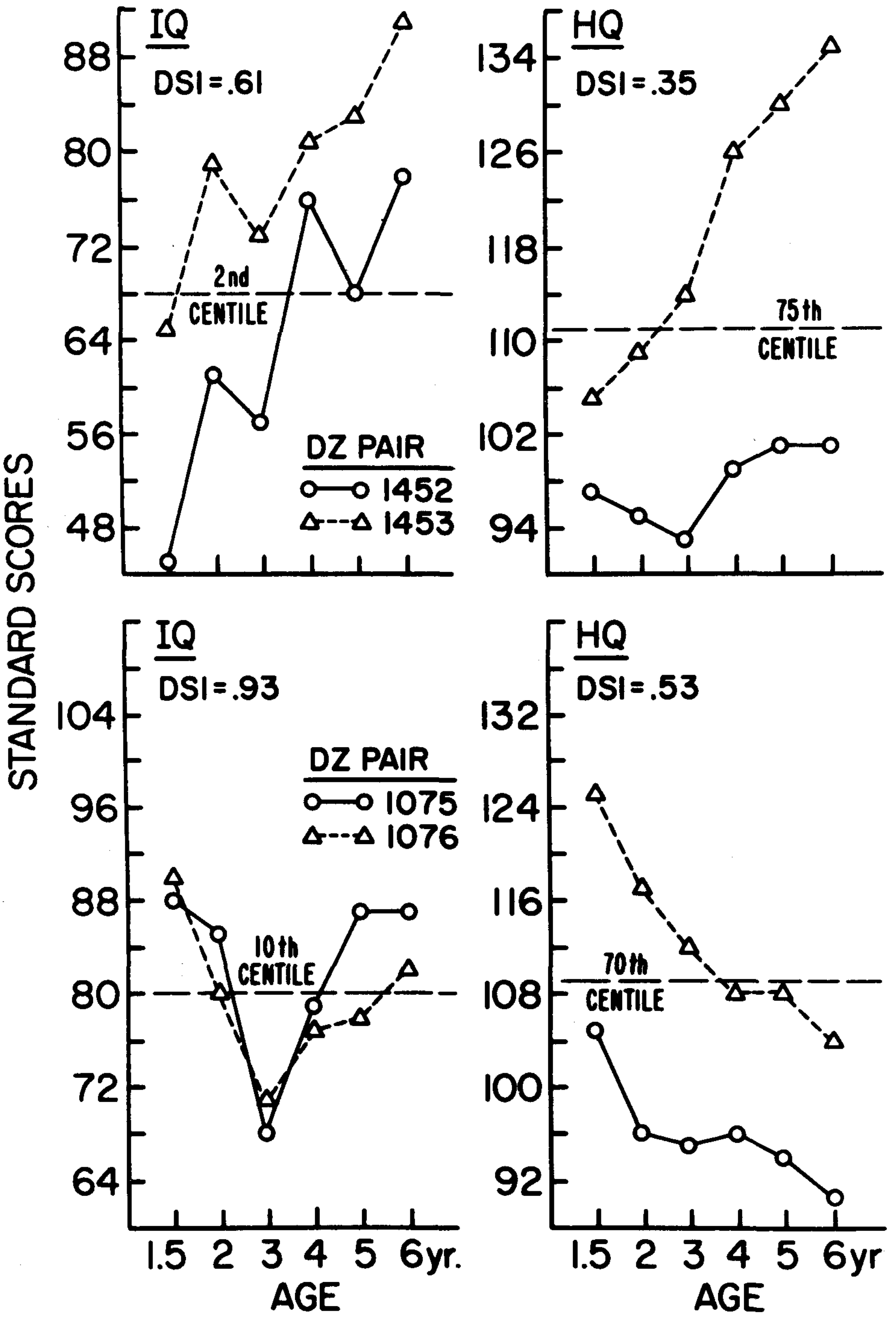

Fig. 2 - Growth curves for height (HQ) and mental development (IQ) for two DZ pairs.

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twins, but there was a sharp rise in concordance at 3 months. Subsequently, the MZ concordance for height moved incrementally upward until reaching R_{MZ} = 0.94 at 6 years.

By contrast, the DZ pairs dropped from an initially high value of R = 0.78 at birth until they reached an intermediate value of R = 0.57 at 6 years. The correlations for the two zygosity groups progressively separated over the first 6 years, in what appeared to be a steady march towards concordance values commensurate with the number of genes shared in common.

For mental development, the differentiation was not so pronounced in the early years, and while the MZ correlations exceeded the DZ correlations, both zygosity groups showed an upward trend in concordance from 12 months to 3 years. After 3 years, however, the DZ correlations dropped steadily to R_{DZ} = 0.59 at 6 years, while the MZ correlations remained in the upper 0.80s.

As the IQ measures progressively stabilized and began to reflect the characteristics of school-age intelligence, the discordance within DZ pairs moved in successive steps toward an intermediate level consonant with the proportion of shared genes. In fact, the DZ correlations for HQ and IQ were virtually the same at 6 years (R_{DZ} = 0.57 and 0.59, respectively), so the anticipated dispersion within DZ pairs was equally well reflected in both measures.

It is perhaps worth noting that the height measures showed the clearest directional trends for the two groups. Each twin appeared to proceed along a targeted pathway of development, with any deviations being diminished over age; and as these deviations were balanced out, the concordance within related pairs closely approximated the number of genes shared in common.

The trends were less clear-cut for mental development until 3 years of age, after which they moved dramatically in the same direction as height. We believe this transition is a joint function of several variables – the changing nature of mental functions during this period [7], stronger effects of common environment at the early ages, reliability of measurement, and perhaps a longer latency for nonshared genes affecting intelligence to reach full expression. Whatever the ultimate explanation may be, it is evident that genetic differences within DZ pairs do not have a direct parallel in IQ differences at this early age.

CONCORDANCE FOR DEVELOPMENTAL TRENDS

While the measures of MZ and DZ concordance at each age are informative, the primary comparison of interest is the degree of synchrony in the growth curves over age. This takes the curves in Figs. 1 and 2 as the prototypes for the analysis, and computes the average degree of concordance for such curves on a sample-wide basis.

The analysis was performed with a repeated-measures ANOVA adapted for twins [8], and the obtained correlations reflect the degree of similarity within pairs for both curve elevation and profile, ie, developmental trends. The results are presented in the Table.

The results reinforced the inferences drawn from the illustrative curves in Figs. 1 and 2. The MZ concordance for height was very high (R_{MZ} = 0.92), making it evident that all MZ pairs in the sample tracked each other as closely as the two MZ pairs in Fig. 1. For IQ, the MZ concordance was slightly lower (R_{MZ} = 0.85); and as the variance figures revealed, the discordance for IQ was nearly twice as great as for HQ. However, when only

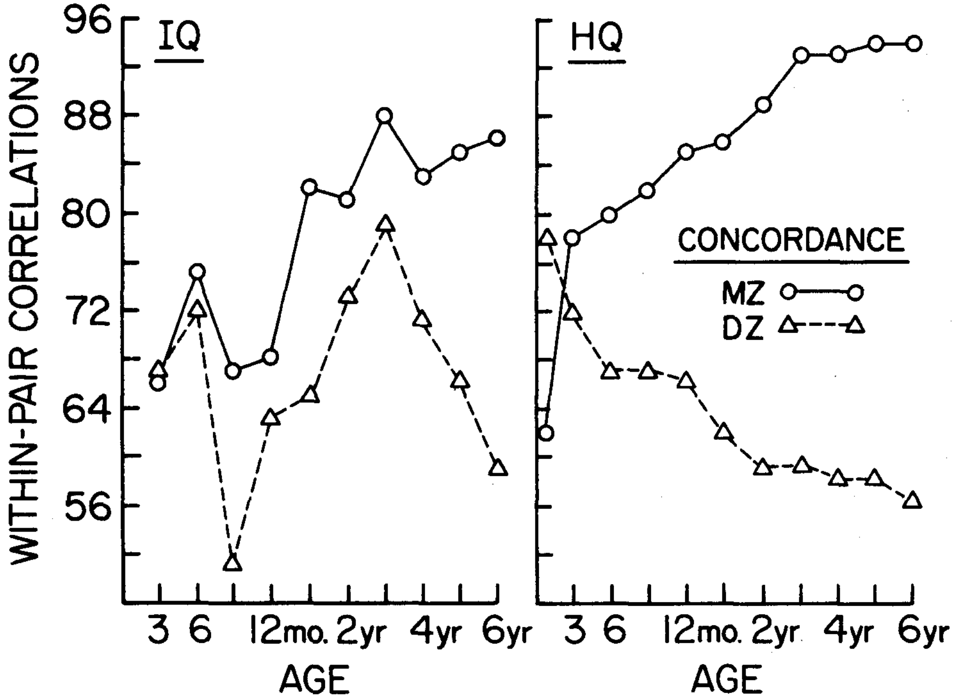

Fig. 3 - Within-pair correlations at each age for MZ twins and DZ twins.

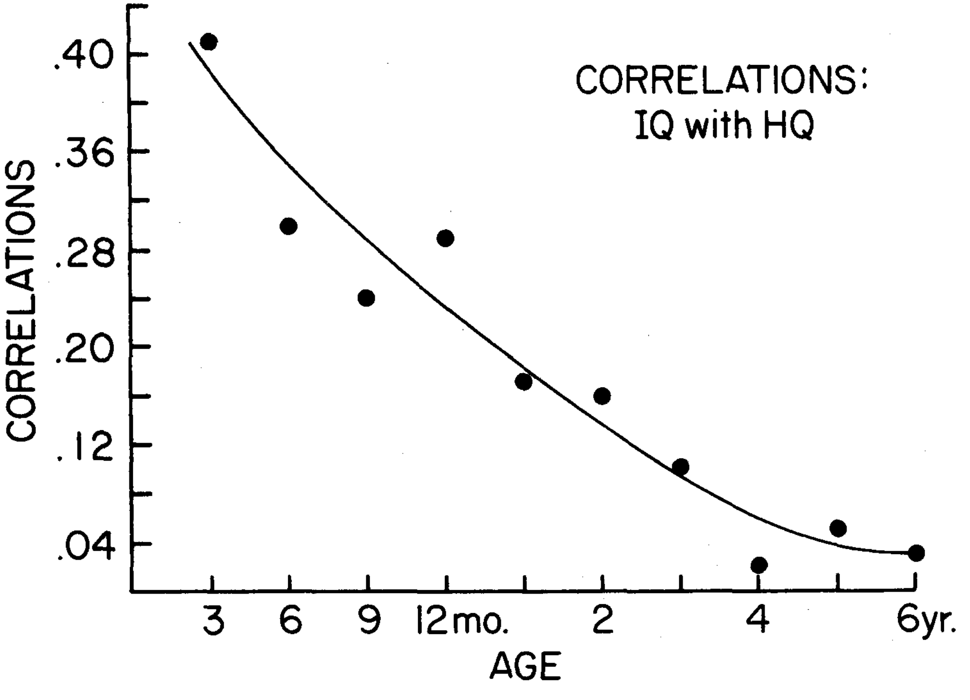

Fig. 4 - Correlation between height and mental development at each age.

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latter is a very powerful age-related process, and virtually all children grow taller and make progressive advances in mental functioning throughout the ages of childhood.

CONCLUSIONS

These results strongly suggest that developmental processes are initiated and guided by timed gene-action systems which are activated in sequential fashion, and on a schedule largely determined by the genotype. In addition to the profound species-wide programming of developmental processes, there are distinctive variations in rate and schedule superimposed upon the main trends, and these furnish the dispersion of individual differences in the population. Each zygote contains a preprogrammed set of instructions that constantly propel the developmental processes along predetermined pathways, and maintains the directional focus in the face of deflecting agents.

While the itinerary of the developmental pathways is in some ways unique for each child, there is a remarkable degree of synchrony for MZ twins, and it must represent a powerful chronogenetic influence on development. We might anticipate that if such influence is clearly demonstrable for mental development, it will also be evident in other behavioral domains as well. Data are currently being collected in the area of infant temperament that will ultimately bear on this issue [3,11].

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Correspondence: Ronald S. Wilson, Ph.D., Child Development Unit, Health Sciences Center, University of Louisville, Louisville, KY 40292, USA.