Ann. Hum. Genet., Lond. (1969), **33**, 71
Printed in Great Britain

The relation of measured intelligence to birth weight and duration of gestation*

By R. G. RECORD, THOMAS McKEOWN and J. H. EDWARDS
Department of Social Medicine, University of Birmingham

There have been two main approaches to investigation of the relation of birth weight to intelligence. In one, birth weights of children of low intelligence are compared with those of children of average or high intelligence. Where the comparison has been between children in ordinary schools, as in Ascher & Roberts's study (1949) in primary, grammar and secondary schools, birth weight differences have usually been unimpressive or absent; but among the subnormal, mean birth weight appears to be reduced and the reduction is present even after exclusion of those whose low intelligence is associated with physical abnormalities (Barker, 1966).

The more usual approach has been to measure the intelligence of children of different birth weights. Numbers investigated by this procedure are, as a rule, rather small and the methods of analysis sometimes make it difficult to assess the results. However, the general conclusion which has been reached is that when children with physical abnormalities—such as blindness, deafness and cerebral palsy—are excluded, the intelligence of the remaining children of low birth weight is about normal (McDonald, 1964). In children of very low weights, however, intelligence appears to be reduced (Drillien, 1964).

The relation of intelligence to duration of gestation is even less well established, but the contemporary viewpoint is probably summarized in Baird's conclusion (1959) that 'there is no clear indication that within wide limits premature expulsion from the uterus does the foetus any serious harm'.

The data used in the present investigation were described in a preceding paper (Record, McKeown & Edwards, 1969). Briefly, they are derived from observations on all (86,630) Birmingham live births in the period 1 January 1950 to 1 September 1954. Verbal reasoning scores from the results of the eleven-plus examinations were matched for 50,172 children and birth weight and duration of gestation (estimated to the nearest week from the first day of the last menstrual period) were available from obstetric records for 41,534 single births.

RESULTS

Since verbal reasoning scores are related to sex and birth rank, account should be taken of these variables in assessing the relation of intelligence to birth weight and duration of gestation in a general population of births.

Figure 1 shows male and female birth weights and V.R. scores, both standardized to the birth rank distribution of the total population of 41,534 children. At different durations of gestation mean weights are higher and mean scores lower for males than for females. Figure 2 gives the same information according to birth rank, standardized for sex differences. At different durations

* This research was assisted by a grant from the Association for the Aid of Crippled Children, New York, and by a Research Grant from the Medical Research Council to one of us (T.McK).

of gestation, mean weights are related directly and mean scores inversely to the number of previous sibs.

Table 1 and Fig. 3 give the distribution of V.R. scores, standardized for sex and birth rank, according to birth weight and duration of gestation. Given the variation noted in Figs. 1 and 2 the need for standardization is evident, since the composition of births by sex and birth rank varies throughout the table. For example, at lower weights there are more females than males; and since females have higher scores than males, the unstandardized distribution would give too high an estimate of scores at low weights.

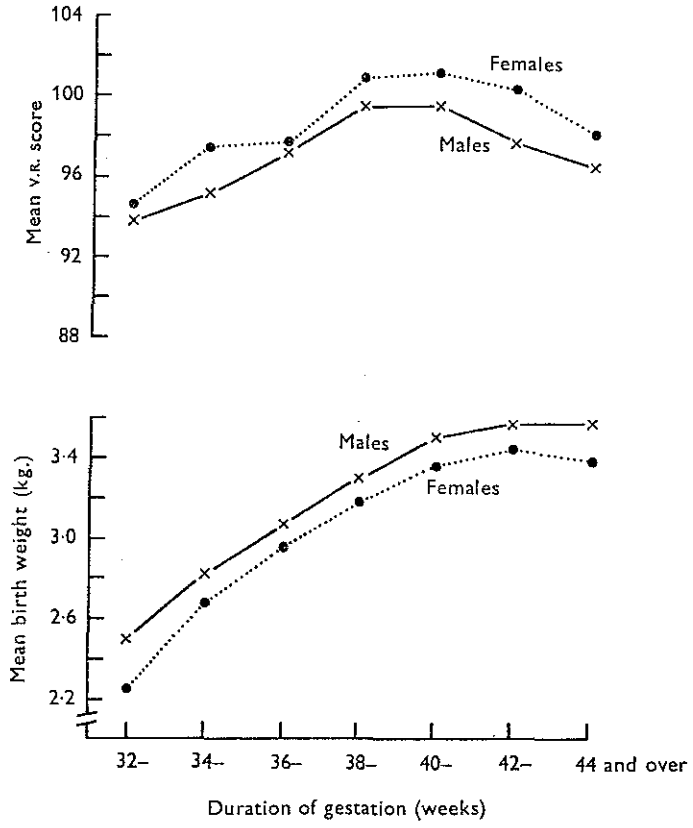

Fig. 1. Mean V.R. scores and mean birth weights (standardized to the birth rank distribution of the whole series) according to sex and duration of gestation.

The standardized distribution (Fig. 3) is ridge-shaped. At a given weight, mean scores increase with increasing gestation to a time characteristic of the weight, after which they decrease slightly. For birth weights of 3·5–4·4 kg. scores are greatest at 40–41 weeks; for lower weights the time when scores are highest is earlier.

The relation of scores to birth weight is less regular. At durations of gestation of 40 weeks or more, scores increase with increasing weight; but at shorter gestations the distribution again appears to be ridge-shaped.

Although there seems to be no objection to the standardization in Table 1 to allow for variation associated with sex and birth rank, the data are complex, and it is reassuring to be able to confirm the conclusions where the correction is unnecessary. Table 2 gives V.R. scores according to birth weight and duration of gestation separately for first-born males and for first-born

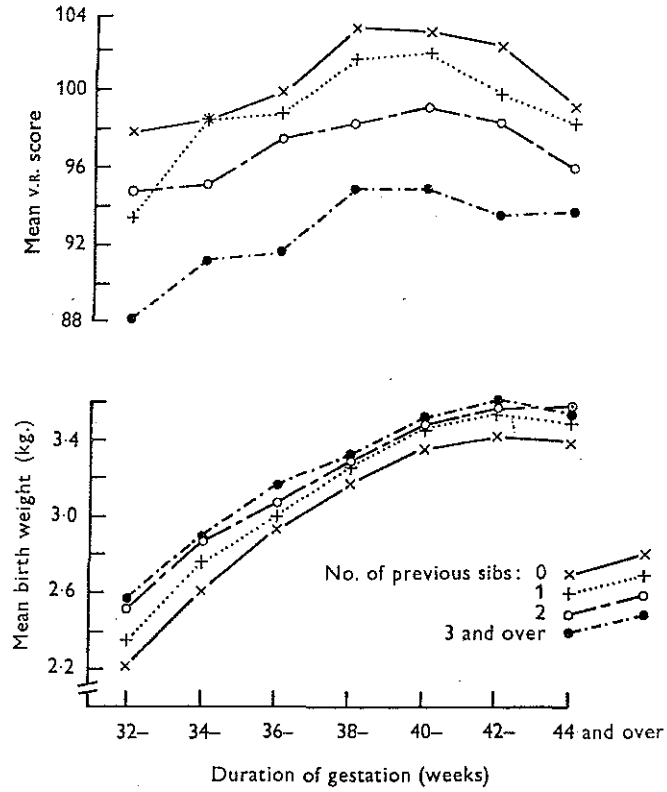

Fig. 2. Mean V.R. scores and mean birth weights (standardized to the sex distribution of the whole series) according to number of previous sibs and duration of gestation.

Table 1. *Mean verbal reasoning scores according to birth weight and duration of gestation*

Duration of gestation (weeks)	Birth weight (kg.) Less than 2·0	2·0–	2·5–	3·0–	3·5–	4·0–	4·5 and over	Total
Less than 32	93·7	—	—	—	—	—	—	94·5
	(60)	(27)	(11)	(15)	(2)	(1)	—	(116)
32–	92·6	95·8	93·8	—	—	—	—	94·2
	(63)	(54)	(38)	(19)	(8)	(4)	—	(186)
34–	94·8	96·7	98·2	93·9	95·5	—	—	96·5
	(67)	(212)	(161)	(125)	(56)	(12)	(3)	(636)
36–	94·2	96·9	97·6	98·3	97·6	95·2	—	97·6
	(52)	(354)	(743)	(632)	(318)	(60)	(11)	(2,170
38–	91·3	96·7	99·1	**101·0**	**101·8**	**101·5**	**100·7**	100·4
	(49)	(541)	(2,667)	(4,310)	(2,192)	(368)	(57)	(10,184)
40–	—	94·5	97·9	**100·1**	**102·1**	**102·8**	**103·2**	100·6
	(23)	(454)	(3,576)	(9,062)	(7,102)	(1,904)	(336)	(22,457)
42–	—	92·8	96·3	98·3	**100·5**	**101·6**	**103·7**	99·3
	(3)	(93)	(678)	(1,864)	(1,737)	(609)	(140)	(5,124)
44 and over	—	—	95·0	96·9	98·5	**100·8**	—	97·5
	—	(13)	(84)	(255)	(230)	(59)	(20)	(661)
Total	93·5	95·9	98·0	100·1	101·7	102·5	103·0	100·2
	(317)	(1,748)	(7,958)	(16,282)	(11,645)	(3,017)	(567)	(41,534

Means have been standardized to the sex/birth rank distribution of the whole series. Numbers of children are given in brackets. Means have not been calculated for cells with less than forty children. Standard errors of the means can be readily calculated from the fact that the distribution of V.R. scores has a standard deviation of 15 points. For example, the standard error of the mean is 1·5 points for a group of 100 children, 0·5 for 900, and 0·3 for 2,500.

females. Values are given only for cells with more than forty observations. The distribution shows the ridge-shaped relation of scores to duration of gestation. The relation to weight is also consistent: from 38 to 39 weeks scores increase with increasing weight. The number of observations is too small to show the relation to weight at shorter gestations.

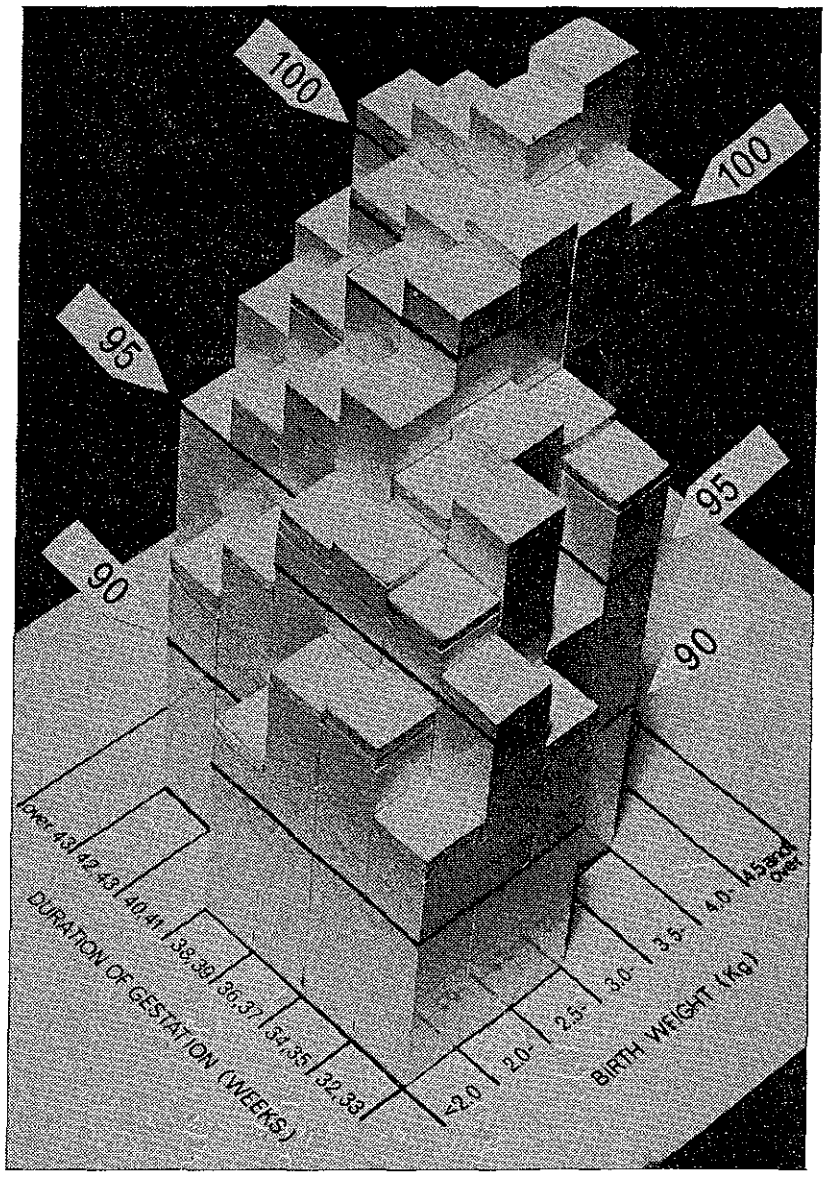

Fig. 3. Mean V.R. scores (standardized for sex and birth rank) according to birth weight and duration of gestation.

The data presented in Tables 1 and 2 appear to justify two main conclusions: (*a*) children born early or late have somewhat lower scores than those from pregnancies of average duration; (*b*) at least from about 38 weeks, mean scores increase with increasing birth weight.

Sib comparisons

Sib data are available for 5042 pairs. Their value for exploring the relation between V.R. scores and birth weight is somewhat restricted by the fact that variation between sibs is not large; correlation between sib scores is 0·55 (Record, McKeown & Edwards, 1969) and between sib weights is 0·50 (Table 3).

Table 2. *Mean verbal reasoning scores of first-born according to sex, birth weight and duration of gestation*

Duration of gestation (weeks)	Birth weight (kg.) 2·0–2·4 M	2·0–2·4 F	2·5–2·9 M	2·5–2·9 F	3·0–3·4 M	3·0–3·4 F	3·5–3·9 M	3·5–3·9 F	4·0–4·4 M	4·0–4·4 F
34–	92·7	—	100·2	—	—	—	—	—	—	—
	(48)	(35)	(40)	(27)	(17)	(23)	(5)	(5)	(2)	(0)
36–	99·9	98·8	101·1	98·6	100·2	102·4	99·0	—	—	—
	(70)	(72)	(171)	(127)	(129)	(102)	(50)	(28)	(8)	(2)
38–	96·9	101·7	101·1	102·5	103·6	105·2	103·8	105·8	105·0	—
	(87)	(128)	(492)	(561)	(823)	(630)	(348)	(199)	(51)	(19)
40–	96·9	98·9	99·6	102·6	102·1	104·2	103·7	105·4	104·3	105·3
	(75)	(118)	(643)	(879)	(1,768)	(1,864)	(1,291)	(916)	(292)	(143)
42–	—	—	99·2	101·6	100·4	103·3	103·6	104·5	103·1	103·0
	(22)	(21)	(135)	(174)	(390)	(413)	(314)	(261)	(94)	(52)
44 and over	—	—	—	—	95·4	102·0	99·4	—	—	—
	(1)	(5)	(8)	(24)	(46)	(43)	(43)	(24)	(4)	(3)

Numbers of children are given in brackets.
Means have not been calculated for cells with less than forty children.

Table 3. *Correlation of birth weight between sibs according to sex*

Sex of pair	Number of pairs	Mean birth weight (kg.) of Older	Mean birth weight (kg.) of Younger	Coefficient of correlation
MM	1224	3·39	3·44	0·50
MF	1305	3·38	3·29	0·50
FM	1215	3·26	3·45	0·52
FF	1298	3·25	3·30	0·51
Total	5042	3·32	3·37	0·50

Table 4 compares V.R. scores of heavier and lighter sibs; here it has been necessary to standardize for birth order. In sibs of like sex, scores are a little higher for the heavier than for the lighter (by 0·9 for males and 0·7 for females). In the case of sibs of unlike sex, since mean scores are higher for females than for males, it has also been necessary to standardize for sex. After this correction the difference between scores of heavier and lighter sibs (0·1) is trivial.

In view of these results, the sib data could not be expected to show considerable score differences according to weight differences. This problem is examined in Table 5. Unfortunately, because of the high correlation between sib birth weights, numbers of pairs differing by more than 1·0 kg. are small. So far as they go, the data are consistent with the conclusion that the small score differences increase slightly with increasing weight differences. In making this comparison it has been necessary to use sib pairs of like and unlike sex and to standardize for sex and birth order.

Correlation between durations of gestation of sibs is approximately 0·2 (Table 6); this is lower than the correlation for birth weight (0·5) and to that extent more promising for examination of the relation to V.R. scores (since the variation between sibs is greater).

Table 7 compares V.R. scores of the older and younger sibs according to duration of gestation classified as short (less than 38 weeks), medium (38–41 weeks) and long (42 weeks and over). The effect of birth order on V.R. scores has been removed by averaging the means of older and younger sibs of the same gestation group. The average score of older and younger sibs of medium

Table 4. *Sib comparison of* V.R. *scores according to relative weight at birth*

Sex	Relative weight	Mean V.R. score of (A) older sib and (B) younger sib		Mean of (A) and (B)	Difference (heavier–lighter)
Male	Heavier	(A) 98·2	(B) 97·8	98·0	
Male	Lighter	(B) 95·3	(A) 99·0	97·1	0·9
		(316)	(406)		
Female	Heavier	(A) 99·7	(B) 99·8	99·8	
Female	Lighter	(B) 98·7	(A) 99·5	99·1	0·7
		(303)	(412)		
Male	Heavier	(A) 96·8	(B) 98·3	97·5	
Female	Lighter	(B) 97·8	(A) 98·6	98·2	−0·7
		(479)	(323)		
Female	Heavier	(A) 98·3	(B) 98·5	98·4	
Male	Lighter	(B) 94·8	(A) 100·3	97·5	0·9
		(206)	(548)		
All pairs of unlike sex*	Heavier	(A) 97·6	(B) 98·4	98·0	0·1
	Lighter	(B) 96·3	(A) 99·5	97·9	

* Giving equal weighting to both types.
Numbers of sib pairs are given in brackets.
2049 pairs have been excluded because sibs differed in birth weight by less than 0·5 kg.

Table 5. *Mean* V.R. *scores* according to birth weight differences between sibs*

	Difference in birth weight (kg.)		
	0·5–	1·0–	1·5 and over
Heavier sibs	98·5	97·7	96·9
Lighter sibs	98·2	97·3	95·4
Difference	0·3	0·4	1·5
No. of sib pairs	2312	518	33

* Standardized to remove variation due to sex and order of birth. This procedure required the exclusion of 130 sib pairs.

Table 6. *Correlation of duration of gestation between sibs according to sex*

Sex of pair	Number of pairs	Mean duration of gestation in days of		Coefficient of correlation
		Older	Younger	
MM	898	279·8	279·1	0·23
MF	967	279·6	279·5	0·22
FM	910	280·2	279·4	0·22
FF	948	279·9	280·8	0·20
Total	3723	279·8	279·7	0·22

gestations (97·5) can then be compared with that of older and younger sibs of short gestations (97·4). Similarly, the average scores of sibs with medium gestations (97·0) can be compared with that of sibs with long gestations (96·7). The very small differences (0·1 and 0·3 respectively) suggest that variation in scores of sibs according to duration of gestation is very small.

Table 7. *Sib comparison of* V.R. *scores according to duration of gestation*

Duration of gestation*	Mean V.R. scores of (A) older sibs and (B) younger sibs		Mean of (A) and (B)	Difference
Medium	(A) 98·6	(B) 96·4	97·5	
Short	(B) 96·8	(A) 98·0	97·4	0·1
	(198)	(204)		
Medium	(A) 97·9	(B) 96·2	97·0	
Long	(B) 95·7	(A) 97·8	96·7	0·3
	(361)	(360)		

Numbers of sib pairs are given in brackets.
* Short: Less than 38 weeks. Medium: 38–41 weeks. Long: 42 weeks and over.

Table 8. *Mean* V.R. *scores according to duration of gestation of sibs*

Duration of gestation of sib (weeks)	Duration of gestation (weeks)					
	34–	36–	38–	40–	42–	44 and over
34–	—	—	98·8	95·5	—	—
	(3)	(12)	(43)	(51)	(9)	(0)
36–	—	—	98·5	97·6	—	—
	(12)	(17)	(123)	(160)	(25)	(7)
38–	95·9	99·0	99·7	99·0	96·4	—
	(43)	(123)	(281)	(905)	(140)	(19)
40–	93·8	97·8	98·9	99·2	97·0	97·3
	(51)	(160)	(905)	(1,193)	(498)	(64)
42–	—	—	96·6	97·3	95·5	89·9
	(9)	(25)	(140)	(498)	(88)	(36)
44 and over	—	—	—	95·6	94·4	—
	(0)	(7)	(19)	(64)	(36)	(2)

Variation due to birth order has been removed by giving equal weight to older and younger sibs.

This conclusion may appear to be inconsistent with the results for the total population of births (Tables 1 and 2) which indicated that for children delivered later than the average duration of gestation, mean V.R. scores decline with increasing duration. A possible explanation of the inconsistency is suggested in Table 8, which examines mean scores of children according to the duration of gestation of their sibs. The scores show in relation to duration of gestation of sibs the same trend as was exhibited in Tables 1 and 2. The results are particularly striking in the case of children delivered at 40–41 weeks. Their mean scores were 95·5 if sib pregnancies were 34–35 weeks; 99·2 with sib pregnancies of 40–41 weeks; and 95·6 with sib pregnancies of 44 weeks and over.

It is not easy to explain this trend, except as an artifact, due to errors in recording duration of pregnancy. There is no other obvious reason why children of 40–41 weeks gestation should have considerably lower scores if their sibs were born very early or very late than if their pregnancies were of average duration. This is the result that might be expected, however, if less intelligent mothers were more likely (*a*) to be mistaken about the date of the first day of the last menstrual period preceding pregnancy, and (*b*) to have children with lower than average scores.

DISCUSSION

The data examined in Table 1 suggest two conclusions. One is that V.R. scores increase with increasing birth weight; the other is that children born early or late have somewhat lower scores than those from pregnancies of average duration.

These results are based on a general population of births, and their interpretation raises the familiar problem of dissociating variation within families from variation between families. A distribution of children according to birth weight is to some extent a distribution according to social class, and hence some correlation between weight and measured intelligence would be expected in view of the correlation between intelligence and social class.

Sib comparisons (Tables 4 and 5) provide little evidence of variation in scores in relation to birth weight within the same families. However, birth weight variation between sibs is relatively small, and the possibility cannot be excluded that large weight differences may be associated with considerable score differences.

The main conclusion which seems justified is that in a general population of births, the substantial increase in V.R. scores with increasing birth weight—approximately 10 points from the lowest (under 2·0 kg.) to the highest (4·5 kg. and over) weight groups—is associated with differences between rather than within families. The differences between families is explained at least in part by social class variation in birth weight, but on the evidence available the possibility cannot be excluded that large birth weight differences have an independent relationship to V.R. scores.

The evidence concerning gestation is in some respects clearer. There is no consistent relationship between V.R. scores and duration of gestation of sibs, although sib variation is considerably greater for duration of gestation than for birth weight. Hence the relation of scores to duration of gestation must also be attributed to differences between rather than within families.

The sib data also suggest an explanation for the association between V.R. scores and duration of gestation in a general population of births. Children of 40–41 weeks gestation had considerably lower scores if their sibs were born very early or very late than if their gestations were of average duration (Table 8). This result is difficult to account for except as an artifact due to errors in recording the onset of pregnancy. It is therefore possible that the association between V.R. scores and duration of gestation in a general population of births may be largely attributable to the fact that less intelligent mothers are more likely to be mistaken about the date of the last menstrual period preceding pregnancy. It seems reasonable to expect these mistakes to be more common in pregnancies said to be shorter or longer than average.

Whether errors of recording provide a full explanation for the association between scores and duration of gestation cannot be decided from the evidence available. But even if they do not, the lower scores of children delivered after long gestations must be interpreted cautiously. The data relating V.R. scores to duration of gestation (Fig. 1) are derived from observations on children delivered after specified numbers of weeks of pregnancy; they cannot be read to correspond with the experience of any one child or any group of children. Thus it cannot be concluded that the 661 children born after 44 or more weeks with a mean score of 97·5, would have had the higher score (100·6) of the 22,457 children delivered at 40–41 weeks if labour had been induced at that time.

This example is a reflection of a general problem associated with investigation of birth weight

and duration of gestation. Even when no associated abnormalities are detected, there must be doubt about the 'normality' of births of very low weight and—if errors of recording could be excluded—of very short and long durations of gestation. In the light of this reservation, as well as of the sib evidence, we conclude that for normal single births variation in V.R. scores in relation to birth weight and duration of gestation is very small.

SUMMARY

Verbal reasoning scores, birth weight and duration of gestation are available for 41,534 Birmingham children born in the years 1950–54. Scores increase with increasing birth weight; and children born early or late have lower scores than those from pregnancies of average duration (Table 1 and Fig. 3).

The same information is available for 5042 sib pairs. These data provide little evidence of variation in scores in relation to birth weight (Table 4) and duration of gestation (Table 7) within the same families. Hence the substantial variation shown in Table 1 is due to differences between rather than within families.

In the case of birth weight, its well recognized relation to social class suggests at least a partial explanation of its association with V.R. scores. In the case of duration of gestation, the association with scores may be largely attributable to errors in recording the onset of pregnancy (Table 8).

It is concluded that for normal single births variation in V.R. scores attributable to differences in birth weight and duration of gestation is very small.

We are greatly indebted to Dr E. L. M. Millar, Medical Officer of Health for Birmingham, and Sir Lionel Russell, Chief Education Officer for Birmingham, for permission to use the records of their departments.

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