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The High Incidence of Reading Disability in Twin Boys and Its Implications for Genetic Analyses

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Abstract. In 1975 the Australian Council of Educational Research (ACER) conducted a nationwide survey of literacy and numeracy in 10- to 14-year olds. A total of 297 of the 12875 children involved were twins. By age 14, only 42% of the twin boys achieved adequate standards of literacy compared with 71% of single-born boys. The deficit in twin girls was much less and twins of both sexes were only moderately behind in numeracy. A survey of 9-13-year-old twin boys in the La Trobe Twin Study (LTS) produced similar results with 75% being below average in reading skills and 23% behind by 18 months or more, despite above average IQs. The ACER data are corroborated by teachers' reports obtained in the same survey, which indicate also how few of the twins with problems are receiving remediation and the high incidence of classroom problems in spelling and reading reversals. The pattern of mistakes twins make on specific items in the ACER survey can be explained as resulting either from specific cognitive deficits or from problems in concentration. The same factors influence performance on different tasks, so that literacy and numeracy are much more closely interrelated in twins than in singletons, and also correlate more with a measure of verbal intelligence. Implications for genetic analysis of scholastic achievement are examined, centering around the different factor structure of abilities in twins and common family environmental effects which are unique to twins.

Key words: Reading disability, Language, Genetic factors, School achievement

INTRODUCTION

While the language problems of twin children have been widely recognised [24], their contribution to subsequent reading disability has received little attention despite the evidence relating reading disability to earlier delays in language acquisition [23] and

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articulation [22]. Some indications do exist that twins, especially boys, have lower reading comprehension and are more likely to have failed a grade and to be involved in speech therapy [26]. Twin males are grossly underrepresented among candidates for the National Merit Scholarship Qualifying Test [12] but it is uncertain whether this is due to sampling problems or to academic disabilities. The South African Talent Survey indicates that twins find it less easy to read quickly and comprehend what is read, a result which is attributed to the higher level of distraction in the twin family situation [3].

In the La Trobe Twin Study [6] distractability characterises twin boys' performance in several situations and relates to their poor performance on those cognitive tasks requiring prolonged concentration [5]. However, it is unclear whether the distractability results from their lack of academic success, or contributes to this lack of success. Problems do appear to originate before the boys commence school. Parental reports of language problems in their preschool twin boys is the best predictor of reading disability as measured by the Neale Reading Test when the boys are between 9 and 13 years of age [9]. In a multiple regression, preschool language delays account for 37% of the variation in overall reading disability, while little is contributed by the WISC-R or any other measures of behavior at the time of the reading test. Reading accuracy is particularly low in the twin boys, while comprehension is less affected.

The generality and permanence of reading deficits in twin boys has been indicated in two preliminary reports [9,19] of analyses of twin-singleton differences in the Australian Council of Educational Research's national survey of literacy and numeracy – the Australian Study in School Performance (ASSP) – carried out in 1975. A total of 297 of the 12875 10- and 14-year olds tested were twins. Using criterion-referenced tests, a level of mastery was defined as achieving 80% correct of all possible items associated with a particular objective [1: Ch. 3]. On this basis, 36% of 10-year-old male twins reached mastery of literacy compared with 50% of male singletons. Corresponding figures for females were 48% and 59%. By age 14, the male singletons and the female twins had improved, but not the male twins. The male figures were then 42% for twins and 71% for singletons, and the female figures 68% and 73%, respectively. Deficits in numeracy were much smaller but showed a similar trend, except that the 10-year-old male singletons were doing as well as the females.

This paper examines further aspects of the ASSP, focusing on the differences teachers perceive between twins and singletons in school work and on the particular areas of deficit within literacy and numeracy. In this way, the contribution of distractability and language deficits to the twin-singleton differences can be assessed. Factor analyses of the different groups examine whether specific factors relevant to the twins' difficulties can be identified. Such a finding has major implications for those current multivariate genetic analyses of ability and achievement data which rely upon twins [14]. The issue is not merely that twins contribute disproportionately to the less able portion of the cohort and hence are less likely to be ascertained, biasing the variance estimates [15], but rather that twins will show a phenotypically different factorial structure of abilities, reflecting unique problems which do not occur in the rest of the population.

MATERIAL AND METHODS

The rationale, design, tests and population results of the ASSP are discussed in three volumes [1,2,10]. Criterion-referenced tests were developed for different aspects of literacy and numeracy (Table 1) to emphasise basic social skills for Australian life and basic classroom skills for further educational progress. Only the reading and numeration tests were analysed here. Three writing tests were also administered to different groups of the sample, but the numbers of twins in each group are too small to warrant inclusion here.

The reading tests comprised 29 items at age 10, and 33 at age 14, with 33 numeration items at each age. Among, eg, the six reading comprehension questions, there was no attempt made to create a simplex scale of increasing difficulty; eg, within the same group of items, only some showed sex differences, some differed between students from state or private schools and some depended on whether English or another language was spoken at home. Diagrammatic stimulus material was used throughout to simplify the task for poor readers [10].

In addition to the measures of reading and numeration, Thorndike's Word Knowledge Test where students must judge synonyms or antonyms for 40 given stimulus words was used to assess verbal ability [10]. Performance on this test related closely to mastery of literacy and, to a lesser extent, mastery of numeracy [1]. The students completed a short questionnaire on basic demography and familiy details. However, parental education and occupation were deliberately omitted, since it was felt some parents may object to this information being given [10]. The teacher most familiar with the student completed a further questionnaire concerning school attendance, performance, need for remedial help, relationship with peers, language and physical or other disabilities.

The sampling comprised a two-state stratified random sample, first of schools and then of students within schools. See [10] for details. The aim was to select at each age range, 10:00 to 10:11 and 14:00 to 14:11, 40 schools and a total of 1000 students in each of the six Australian states and 20 schools and 500 students in each of the two territories, a total of 7000 at each age. From each selected school or "pseudoschool" (a combination of very small schools in the one region), 25 students were picked with birthdays on the 10th day of any appropriate month. If insufficient, those with birthdays on th 11th, etc, were used. The achieved sample was 6628 10-year-olds and 6247 14-year-olds of whom 168 and 129, respectively, were twins. Thus, one child in 43.36 is a twin, a proportion consistent with the Australian Bureau of Statistics livebirth and perinatal mortality statistics for 1961-1965.

Although most results concern the proportion of students successfully completing each item, the conventional binomial techniques for calculating standard errors for such data may underestimate the sampling errors in situations such as the ASSP where sampling is stratified rather than random. Means of overcoming this problems have been developed [10: Ch. 2].

RESULTS

Word Knowledge Test

Table 2 indicates the verbal ability of the ASSP students as measured by this test. Four scores can be derived for (a) the number of items attempted out of the 40 possible, (b) the number wrong, (c) the number missed, and (d) the total number correct which is derived from a-b but does not equal it exactly.

All analyses have been done for males and females separately because of the prominence of sex differences in twins [5,11].

At both ages, singletons do better than twins especially in the case of males. But the reason for the poorer performance changes with age. At age 10, twins predominantly try fewer items than singletons, but get no more wrong of the ones they try. At age 14, twins are trying as many but getting more wrong. The pattern at age 10 is perhaps more consistent with the discussion earlier that twins have a particular problem in prolonged concentration and with the observation that twin boys are less likely to work steadily in the test situation [6]. However, by age 14, their word knowledge is less than that of the singletons and they make more mistakes.

Teacher's Questionnaire

In the present paper, only those questionnaire items are considered which relate specifically to literacy and numeracy or to problems on the word knowledge test. Those items

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dealing with social interactions at school are not considered in detail even though across the entire ASSP sample poorer numeration and reading (except for simple sentences at age 14) characterise children who are rejected by others, demand attention, are unable to cooperate with peers, isolate themselves and are shy [1: Ch.11]. The twins showed no differences from the singletons at age 10 but by age 14 the female twins were much less cooperative with their peers than the singleton girls (on a five point scale, $\chi^2_4 = 25.33$, $P < 0.001$), while the twin boys were slightly shyer than their singleton counterparts ($\chi^2_4 = 10.59$, $P < 0.05$). The problem with adolescent twin girls has been noted before [6,11] in terms of the difficulty they find in using anything other than their uniqueness as twins as a basis for friendships. However, the relative absence of any social difficulties in twin boys who have much greater academic difficulties would indicate that such behavioral problems are not a major contributor to the twins' academic problems.

Table 3 compares twins and singletons on the teachers' perception of the need for remedial reading and numeracy and on the presence or absence of difficulty in three areas of classroom work (two items on difficulties in writing and in copying work are excluded as there were no twin-singleton differences). The results confirm the much higher need for remedial reading in twin boys, particularly by the age of 14, when the twin girls and, to a lesser extent the singleton boys, have improved. It is interesting that the twin boys have an even larger deficit in numeration than in reading.

The comparison of those children receiving remedial help with those indicated by the teacher as needing but not receiving it shows a sex difference in that 2/3 of the 10-year-old twin boys who need it are receiving remediation compared with 1/3 of the twin girls. This difference is significant (χ^2_1 with Yates' correction = 5.64, $P < 0.05$). It is not clear if this reflects an awareness of how female twins are more likely to "grow out" of the problem. Remedial help is less readily available in the secondary schools and 29.8% of 14-year-old twin boys need but are not receiving remedial numeration, with 22.6% not receiving remedial reading. With these figures, it is not surprising that the deficits in twins appear to be permanent, when studied in population-based samples such as military conscripts [7] and possibly also the candidates for the National Merit Scholarship Qualifying Test [12].

The teachers' comments on classroom difficulties show that the twin boys' difficulties extend to spelling problems. They also have difficulty following verbal instructions at age 10, and at age 14 are persisting in reading reversals, a habit which the singleton boys and twin girls have lost. The changing pattern of deficits in the twin boys is thus consistent with that seen on the Word Knowledge Test. At age 10, difficulties in following verbal instructions can perhaps be attributed to their distractability and unwillingness to cooperate, but by age 14 there is a definite literacy problem not found in other children.

Reading and Numeration Tests

Given the large number of items comprising the reading and numeration tests – 62 at age 10, 66 at age 14 – a first step has been a factor analysis with Varimax rotation separately on each group of children. While twins are generally considered to have a verbal deficit [20], it has been proposed that this may affect a wide range of apparently nonverbal skills as well [5,28]. The summary of the factor analysis in Table 4 confirms this. At both 10 and 14 years, the three main factors in the singletons are quite discrete, involving specific aspects of numeration, of syntax and of comprehension, both literal and inferential.

The factors from the twins are quite different. In some cases they are a combination

TABLE 1 - Reading and Numeration Tests in the Australian Study in School Performance - details are in [10]

Reading

Common to both 10- and 14-year olds

1. Knowledge of the alphabet.
2. Simple sentences - a test of basic reading comprehension where students had to match sentences with pictures.
3. Linguistic competence - a test of the idiomatic use of language by selecting the appropriate word or phrase, eg, "he has (going, go, to go) to school very early".

Different passages for 10- and 14-year olds

4. Reading comprehension using stimulus material typical of school text books.
5. Newspaper - a specially prepared paper where students were required (a) to locate a particular news item using directory and indexing skills, (b) to scan to find specific information in an article, and (c) to interpret the meaning of words and phrases.

Numeration

Common to both 10- and 14-year olds

1. Reading measuring instruments.
2. Basic arithmetic tables.
3. Using basic arithmetical operations with whole numbers.
4. Using basic arithmetical operations with common fractions.
5. Reading values from graphs and tables.
6. Applying arithmetical operations to concrete situations, eg, calculating change.
7. Calculating time measurements.
8. Reading time.

Specific to 10-year olds

1. Counting.
2. Using spatial knowledge, eg, finding the closest item to a given point.
3. Estimating magnitudes, eg, Is a tall man (1,2,4 or 6) metres tall?

Specific to 14-year olds

1. Using decimals.
2. Calculating geometric quantities, eg, comparing areas.
3. Interpreting plans and maps.

TABLE 2 - Means ± Standard Errors for the Word Knowledge Test of the Australian Study in School Performance

	Males		Females	
	Twins	Singletons	Twins	Singletons
10 year olds				
(a) Total attempted	23.92 ± 0.78	26.02 ± 0.13**	23.44 ± 0.89	25.73 ± 0.14*
(b) Number wrong	10.80 ± 0.64	10.17 ± 0.13	10.54 ± 0.92	9.96 ± 0.17
(c) Number missed	5.97 ± 0.99	4.27 ± 0.14*	6.98 ± 1.17	5.44 ± 0.17
(d) Total correct	13.64 ± 1.05	16.88 ± 0.20**	13.75 ± 1.48	19.92 ± 1.01*
N	108	3328	60	3300
14 year olds				
(a) Total attempted	22.51 ± 0.89	24.48 ± 0.12*	23.98 ± 0.87	24.43 ± 0.13
(b) Number wrong	12.00 ± 0.96	9.78 ± 0.13**	12.30 ± 1.25	9.76 ± 0.15**
(c) Number missed	6.52 ± 1.16	6.30 ± 0.16	4.61 ± 0.83	6.67 ± 0.17
(d) Total correct	11.57 ± 1.21	16.03 ± 0.39***	14.52 ± 1.10	17.55 ± 0.81*
N	67	3150	62	3097

Asterisks refer to tests of significance of the twin-singleton difference for that sex. Items not indicated were not significant.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

TABLE 3 - Teacher's Reports of Classroom Problems in the Australian Study in School Performance

	Males				Females			
	Age 10		Age 14		Age 10		Age 14	
	Twins	Singletons	Twins	Singletons	Twins	Singletons	Twins	Singletons
Numeration								
Needs and receives remedial help	18.0	10.9	8.8	4.7	12.7	7.5	3.5	3.0
Needs but does not receive help	21.0	12.1	29.8	13.7	11.1	11.9	14.0	9.4
Does not need help	61.0	77.0	61.4	81.6	76.2	80.6	82.5	87.6
	$\chi^2_2=13.79^{***}$		$\chi^2_2=15.17^{***}$					
Reading								
Needs and receives remedial help	23.0	18.0	11.3	10.5	10.9	8.7	3.4	4.3
Needs but does not receive help	10.0	8.2	22.6	10.7	20.3	5.9	10.3	5.6
Does not need help	67.0	73.7	66.1	78.8	68.8	85.3	86.2	90.1
			$\chi^2_2=9.11^{**}$		$\chi^2_2=25.5^{***}$			
Percentage of Children having difficulties with								
Verbal instruction	19	10.9	11.1	8.6	10.6	7.2	8.3	4.8
	$\chi^2_1=5.64^{*}$							
Spelling	39	22.8	31.7	16.3	16.9	11.4	10.2	7.6
	$\chi^2_1=13.37^{***}$		$\chi^2_1=9.48^{**}$					
Reading reversal	11.1	9.9	15.9	6.3	12.3	5.0	0	2.5
			$\chi^2_1=7.78^{**}$		$\chi^2_1=6.29^{**}$			

Data are the percentage of children in each class with χ^2s indicating any significant twin-singleton differences (Numbers in each group are as in Table 2).
$^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

TABLE 4 - The Results of Factor Analyses of Reading and Numeration Items in the Twins and Singletons in the Australian Study in School Performance - Description of the First Three Factors and the Three Items Loading Most Highly on Each Factor. (In brackets are the correlations of items with factors).

Males, Age 10			
		Male Twins	
Factor number	1	2	3
Proportion of variance	25.0	7.6	7.1
Description of factor	Stimulus-response items	Scanning and concrete numeration	Inferential and literal comprehension
Item 1	One digit addition (.86)	News information 7 (.64)	Read paragraph 4 (.60)
2	One digit subtraction (.65)	Adding times (.58)	Read paragraph 1 (.58)
3	One digit multiplication (.62)	Linguistic competence 1 (.50)	Read calendar date (.41)
		Male Singletons	
Factor number	1	2	3
Proportion of variance	39.8	9.2	6.4
Description of factor	Inferential comprehension	Basic numeration	Syntax and literal comprehension
Item 1	Read paragraph 2 (.46)	One digit addition (.66)	Linguistic competence 2 (.46)
2	News comprehension 5 (.45)	One digit multiplication (.64)	Linguistic competence 4 (.40)
3	Read paragraph 2 (.45)	One digit subtraction (.59)	Linguistic competence 5 (.39)
Number of the first ten items (out of 62) overlapping in twins and singletons	0	1	2
Males, Age 14			
		Male twins	
Factor number	1	2	3
Proportion of factor	27.5	8.3	7.5
Description of factor	Comprehension and complex numeration	Concrete numeration and inferential comprehension	Simple numeration and literal comprehension
Item 1	News comprehension 6 (.71)	Calculate interest (.84)	Two-digit subtraction (.67)
2	Read paragraph 3 (.65)	Two-digit multiplication (.59)	News comprehension 3 (.65)
3	Money division (.64)	Calculate money (.54)	Reading graph (.56)

		Male singletons	
Factor number	1	2	3
Proportion of factor	29.8	10.8	7.4
Description of factor	Concrete numeration	Inferential comprehension	Simple and literal comprehension
Item 1	Decimal subtraction (.51)	News comprehension 6 (.48)	Simple sentence 5 (.86)
2	Calculate interest (.41)	News comprehension 1 (.40)	Simple sentence 4 (.75)
3	Calculate distance and speed (.41)	News comprehension 2 (.40)	Simple sentence 2 (.39)
Number of first ten items (out of 66) overlapping in twins and singletons	1	1	0
Females, Age 10			
		Female twins	
Factor number	1	2	3
Proportion of variance	23.0	10.4	8.4
Description of factor	Syntax and literal comprehension	Complex numeration	Scanning and stimulus-response
Item 1	Linguistic competence 3 (.84)	Read calendar date (.77)	One digit subtraction (.86)
2	Linguistic competence 4 (.76)	Money addition (.75)	One digit addition (.85)
3	Money multiplication (.70)	Linguistic competence 6(.57)	News information 6 (.52)
		Female singletons	
Factor number	1	2	3
Proportion of variance	36.2	8.3	6.6
Description of factor	Inferential comprehension	Basic concrete numeration	Basic abstract numeration
Item 1	Read paragraph 3 (.55)	Money subtraction (.56)	One digit multiplication (.69)
2	Read paragraph 4 (.54)	Money multiplication (.45)	One digit addition (.64)
3	News comprehension 5 (.49)	Time division (.39)	One digit subtraction (.58)
Number of the first ten items (out of 62) overlapping in twins and singletons	0	3	3
Females, Age 14			
		Female twins	
Factor number	1	2	3
Proportion of variance	27.5	10.1	7.1
Description of factor	Inferential comprehension and concrete numeration	Syntax and concrete numeration	Comprehension and simple numeration
Item 1	News comprehension 9(.82)	Linguistic competence 1 (.65)	Long division (.68)
2	Concrete addition and subtraction (.71)	Concrete multiplication (.61)	Concrete addition (.57)
3	Two-digit division (.60)	Concrete multiplication (.61)	News comprehension 2 (.57)
		Female singletons	
Factor number	1	2	3
Proportion of variance	46.1	20.0	5.4
Description of factor	Syntax	Complex numeration	Inferential and literal comprehension
Item 1	Linguistic competence 7 (.64)	Subtract decimals (.51)	Read paragraph 1 (.44)
2	Linguistic competence 5 (.64)	Concrete multiplication (.50)	News comprehension 6 (.42)
3	Linguistic competence 6 (.61)	Concrete addition (.43)	Read paragraph 6 (.40)
Number of the first ten items (out of 66) overlapping in twins and singletons	0	1	2

See text for details and sample sizes and see [2] for further details of the items.

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of reading and numeration items. For example, in the 14-year-old male twins, four of the ten highest loading items on factor 1 are numeration items and six are reading ones. Factors 2 and 3 each have six numeration and four reading items. Another difference between the twins and sigletons is that the major factors often represent simpler skills. Thus, while Factor 1 for both male and female 10-year-old singletons is an inferential comprehension factor, the corresponding factors for twins reflect simple stimulus-response items such as basic syntax and arithmetic tasks involving no processing. In the twins, it is often necessary to distinguish basic numeration from problems involving abstraction of numerical data from concrete examples, eg, adding up a shopping list. One result of the twin-singleton difference is indicated at the bottom of each part of Table 4 in that there is almost no overlap between the items contributing to comparable factors in the twins and singletons.

Table 5 provides a possible explanation for the results in terms of the test construction. With items chosen to give 80% mastery [10], this means, for example, that a 10-year-old must get 24 of the 29 reading items at that age correct to have mastery of literacy, while at 14 years, 27 of the 33 reading items must be correct. Given the much higher incidence of mastery in singletons – the column and row totals in Table 5 – many of these singletons are recording uniformly high scores on both literacy and numeracy and hence contributing little to the variance in the factor analysis. The much lower scores of the twins would allow a greater scope for variance across items, and hence a different factor structure is found, reflecting the items they get wrong more than those they get right. In addition, singletons will be more likely to get all the simple items correct and vary only on the complex ones, while twins vary on the simple ones and get few of the complex ones correct. Thus the factors in the singletons load on complex items and the factors in twins on simple ones.

The same phenomenon could explain the results in Table 6 where the dependence of mastery on Word Knowledge Test performance has been assessed by the asymmetric eta statistic [18]. (Eta squared is an estimate of the amount of variance in mastery accounted for by the Word Knowledge Test score). The consistently higher eta values for twins may reflect only their greater variance in mastery.

However, this explanation of the greater relation between literacy, numeracy and word knowledge in twins cannot just be a scalar phenomenon, given that it occurs in female twins who by the age of 14 are achieving mastery almost as frequently as the singletons and, at least for reading, much more than any of the 10-year-olds. There must be a generalised deficit in twins, impairing performance on both the reading and numeration items.

The more complex skills are the ones which suffer as seen in Table 7. At age 10 there are no deficits in simple one-digit addition or subtraction, in reading the alphabet, in the literal comprehension of simple sentences or in extracting discrete information from newspapers by simple scanning and indexing skills. This point is illustrated further by the differences between the twin boys and girls. The girls do not have the same deficit as the boys in basic linguistic competence (syntax) or in literal comprehension of the paragraph they have to read, but fall behind the singleton girls far more on the more complex inferential comprehension of the paragraph.

A similar pattern emerges at age 14. The basic skills have improved so that there are no longer deficiencies in basic arithmetic or in linguistic competence, while problems remain with more complex numerical skills and with comprehension.

TABLE 5 - Relation Between Percentage of Children Achieving (A) or not Achieving (N) Mastery of Literacy and Numeracy in the Australian Study in School Performance

			Twins				Singletons		
10-year olds			Numeracy				Numeracy		
			N	A			N	A	
Males	Literacy	N	36.6	27.7	64.4	N	22.4	28.1	50.5
		A	5.0	30.7	35.6	A	4.1	45.4	49.5
			41.6	58.4			26.5	73.5	
			N	A			N	A	
Females	Literacy	N	28.3	23.9	52.2	N	19.5	21.2	40.7
		A	4.5	43.3	47.8	A	5.8	53.5	59.3
			32.8	67.2			23.5	74.7	
14-year olds									
			N	A			N	A	
Males	Literacy	N	37.3	20.9	58.2	N	16.5	12.2	28.7
		A	4.5	37.3	41.8	A	8.3	63.0	71.3
			41.8	58.2			24.8	75.2	
			N	A			N	A	
Females	Literacy	N	22.6	9.7	32.3	N	15.5	11.7	27.2
		A	11.3	56.4	67.7	A	10.7	62.1	72.8
			33.9	66.1			26.2	73.8	

TABLE 6 - Eta Statistics for the Association of Mastery of Literacy and Numeracy with Performance on the World Knowledge Test (WKT) in the Australian Study in School Performance

	Males		Females	
	Twins	Singletons	Twins	Singletons
10-year olds				
Literacy and WKT	0.5605	0.5642	0.6571	0.5056
Numeracy and WKT	0.6246	0.4836	0.6933	0.4603
14-year olds				
Literacy and WKT	0.8080	0.5732	0.7000	0.4691
Numeracy and WKT	0.7522	0.5036	0.6990	0.4878

This distinction is consistent with the reports from preschool [16] and both younger [27] and older [8] school age twins that twins of differing ability are differentially affected by the twin situation. Twins may acquire basic skills, but for various reasons, including problems of parent-child interaction [13] and an inability to benefit from complex verbal interaction of this sort [16], may not achieve more complex processing. What is yet uncertain is whether the most able twins are under-achieving [27] or whether they are coping, and only the less able twins are not reaching their potential [7].

Lack of concentration, as suggested earlier [3], may contribute to these deficits, since it would predict particularly poor performance, for the 14-year-olds, on the newspaper comprehension test, which has been recognised as being too long and detailed for many students [1]. Similarly, the two numeration items with the largest twin-singleton difference were detailed rather than complex questions: finding the closest number involved picking the number closest to 85,000 out of a 10 X 10 matrix of five-digit numbers, while subtracting money involved calculating the difference in price between two cars valued at $ 2960 and $ 3202. Although lack of concentration is one explanation, it cannot be distinguished from problems with short-term memory, visual sequencing and visual information storage, all of which have been found to characterise the poor reader [17].

DISCUSSION

These data have added to the evidence [9] that twin boys have, and retain through adolescence, a specific deficit in literacy and numeracy, largely unrelated to intelligence. Even if word knowledge is taken as an adequate measure of verbal intelligence, the small deficit it shows in male twins is insufficient to explain their much higher incidence of academic achievement problems. By age 14, word knowledge and mastery are much more closely related in twins than in singletons (Table 6) and it could be argued that these reflect a common problem, possibly in concentration, as much as any dependence of academic mastery upon word knowledge. Alternatively, the greater time parents of singletons can devote to their children [13] may mean the children can achieve mastery despite less adequate verbal intelligence.

The limited value of lower verbal intelligence as an explanation for poor mastery in the twin boys is best seen by the age changes which are more consistent with a problem of reading acquisition than of long-term deficits in intelligence. At age 10, all boys and the twin girls have a higher incidence of reading reversals (Table 3), but by age 14 it is only the twin boys in whom this problem remains. A similar pattern is seen for mastery of literacy and, to a lesser extent, numeracy (Table 5).

If academic delays are more common in twin boys, what are the implications for genetic analysis using twin children? The first issue must be whether twins develop reading disability for different reasons to singletons, in which case a genetic analysis using twins will say little about the determinants of reading disability in the singleton population. One example would be the reported relation between preschool language problems and later reading skills [9], such that in a multiple regression, preschool language determined 37% of the variance in reading. The intraclass correlations for preschool language problems were 0.99 and 1.00 for MZ and DZ twins, respectively, emphasising the role of the twin situation in determining language problems – either both have problems or both do not. This effect of the twin situation and its prediction of reading will show up in the genetic analysis of reading as a large common family environmental

TABLE 7 - Difference Between Twins and Singletons in the Percentage Correctly Completing Items* on the Reading and Numeration Tests of the Australian Study in School Performance.

Items	Singleton-twin difference in percent achieving mastery	
	Males	Females
10-year olds		
One-digit multiplication	14	–
One-digit division	17	–
Two-digit subtraction	26	17
Two-digit multiplication	22	–
Subtract concrete articles	14	12
Divide concrete articles	16	24
Fractions with concrete articles	22	16
Adding times	21	17
Linguistic competence 1	12	–
Linguistic competence 2	13	–
Linguistic competence 3	11	–
Linguistic competence 5	11	–
Read paragraph 1 (literal)	13	2
Read paragraph 2 (inferential)	18	20
Read paragraph 3 (inferential)	26	16
News comprehension 1 (inferential)	18	–
News comprehension 3 (literal)	14	–
News comprehension 4 (inferential)	16	–
News comprehension 5 (inferential)	10	10
14-year olds		
Reading graph	13	–
Subtract times	17	–
Find closest number in series	23	–
Subtract money	26	–
Multiply concrete articles	20	–
Multiply and subtract concrete articles	20	–
Calculate distance and speed	17	14
Read instrument	18	–
Calculate interest	17	–
Calculate money	17	–
Compare volumes	19	–
Add concrete articles	15	11
Long division	14	–
Read paragraph 1 (literal)	23	–
Read paragraph 2 (literal)	16	–
Read paragraph 3 (inferential)	12	–
Read paragraph 4 (literal)	15	–
Read paragraph 5 (inferential)	24	–
Read paragraph 6 (inferential)	16	–
News comprehension 1 (inferential)	19	–
News comprehension 2 (literal)	27	–
News comprehension 3 (literal)	19	–
News comprehension 5 (inferential)	18	–
News comprehension 6 (inferential)	23	–
News comprehension 8 (inferential)	19	–
News comprehension 9 (inferential)	15	–

* Only those items differing at $P < 0.01$ are listed. – indicates no significant difference. "Literal" and "inferential" refer to type of comprehension involved. See [2] for further details of the items.

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influence specific to twins.

A second issue with twins arises from the factor analysis in Table 4, the relationship between mastery of literacy and numeracy in Table 5, and the relation of these to word knowledge in Table 6, all of which suggest that the components of ability and achievement are interrelated differently in twins than in singletons. Reading and numeration skills overlap much more in the twins, because they are both affected either by specific cognitive deficits or by a lack of concentration. Despite the efforts to reduce the role of reading in the numeration items, this may play a factor in the twins. At age 14, there are far fewer twin boys who achieve mastery of literacy but not numeracy than the reverse (Table 5), suggesting that literacy may be a prerequisite for numeracy as measured in this situation. In the other three groups of 14-year olds, the proportions achieving one but not the other are fairly symmetrical.

The interrelation between abilities becomes important because of the growing interest in multivariate behavior genetics [5] and the development of covariance structure methods to test hypotheses about the genetic and environmental relationship between variables [14]. The examples to date have relied solely upon twins and there are thus no checks on whether the results are applicable to singletons. Yet, the outcome of at least one analysis [14] of the five Primary Mental Ability subtests (Numerical ability, Verbal comprehension, Spatial ability, Word fluency, and Reasoning ability) is consistent with a large common-family environmental effect (E_2) arising from the twin situation. With the exception of Spatial ability, the intercorrelations of the E_2 component for the subtests are very high: Numerical, Verbal, and Word fluency correlate 1.00 with each other and all correlate 0.79 with Reasoning. This result may be genuine or may reflect the same problem with twins discussed here, that they have some disability induced by the twin environment which leads to their results on different tests being much more closely related. Comparable genetic analysis involving singletons are needed to resolve this question.

A final problem for genetic analysis concerns the heterogeneity of reading and other academic disabilities. Distinctions within reading disability based on relationships with lateralisation, spelling problems, etc, have been proposed [22] but are not yet agreed upon. If the disputed phenomenon of mirror-imaging in MZ twins [4,25] is established, then the possibility arises of MZ twins both with reading disabilities, but of different types, according to their hemispheric specialisation. Such a possibility is supported by differences within some of the MZ twin pairs seen at La Trobe for clinical help with reading problems, but needs further study. It may be unwise to record MZ twins as concordant just because they are both diagnosed as reading disabled, without checking whether they are also concordant for some of the other variables believed to be associated with heterogeneity of reading disability [17,22].

CONCLUSIONS

Apart from any implications for genetic analysis with twins, the major significance of these results is for the education of twins. Previously only minimal attention [9,11,26] in research has been paid to the likelihood of academic problems in twins. The high proportion of 14-year-old twin boys needing but not receiving remedial numeration and reading indicates that a similar lack of attention has occurred within the educational system.

Research and treatment on this problem must proceed at two levels. One is to begin with preschool twins who are exhibiting the language problems which are the antecedents of the academic deficits [9,13]. If language problems can be reduced, then subsequent reading problems may not occur. Secondly, more examination is needed of the exact problems experienced by the twins who do not achieve mastery of literacy and/or numeracy. In this paper, twins as a group have been compared with singletons. The next step is to compare twins and singletons who fail to achieve mastery of literacy and numeracy and to see if they exhibit similar patterns of deficit. For example, it has been argued that lack of concentration is a particular problem arising through the twin situation and may not apply to singletons [3]. Similarly, there are unusual patterns of lateralisation in twins both at the level of hand preference [4] and dichotic listening [25], and the possibility that these may contribute to academic deficits peculiar to twins cannot be ignored in future research.

These deficits of twins in literacy and numeracy are much greater both in magnitude and in consequence than their often-reported deficits in verbal intelligence [8,20]. Greater attention to twins and their problems in school may not only be of practical help to the twins but may also provide a greater understanding of the mechanisms by which the acquisition of literacy and numeracy can be disrupted. The Waltham Forest longitudinal study [21] has provided invaluable information on the educational and other consequences of early emotional disturbance in children and, given the wide-ranging nature of the stresses in the multiple-birth family [6,11,19], a comparable study of twins' development from an educational perspective is long overdue.

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REFERENCES

1. Bourke SF, Keeves JP (1977): Australian Studies in School Performance Vol III. The Mastery of Literacy and Numeracy: Final Report. Canberra: Australian Government Publishing Service.
2. Bourke SF, Lewis R (1976): Australian Studies in School Performance Vol II. Literacy and Numeracy in Australian Schools: Item Report. Canberra: Australian Government Publishing Service.
3. Clark P (1980): Language retardation in twins - The wider implications. Paper delivered at National Psychology Conference. Reprinted as Occasional Paper of the Psychology Department, University of Natal.
4. Hay DA, Howie PM (1980): Handedness and differences in birthweight of twins. Percept Mot Skills 51:666.
5. Hay DA, O'Brien PJ (1981): The interaction of family attitudes and cognitive abilities in the La Trobe Study of Behavioral and Biological Development. In Gedda L, Parisi P, Nance WE (eds): Twin Research 3: Part B. Intelligence, Personality and Development. New York: Alan R Liss, p 235-250.
6. Hay DA, O'Brien PJ (1983): The role of parental attitudes in the development of temperament in twins at home, school and in test situations. Acta Genet Med Gemellol 33:191-204.
7. Husen T (1959): Psychological Twin Research. Stockholm: Almqvist and Wiksell.
8. Husen T (1963): Intra-pair similarities in the school achievements of twins. Scand J Psychol 4:108-114.
9. Johnston CJ, Prior M, Hay DA (1984): Prediction of reading disability in twin boys. Dev Med

Child Neurol, in press.
10. Keeves JP, Bourke SF (1976): Australian Studies in School Performance. Vol I. Literacy and Numeracy in Australian Schools: A First Report. Canberra: Australian Government Publishing Service.
11. Koch HL (1966): Twins and Twin Relations. Chicago: University of Chicago Press.
12. Loehlin JC, Nichols RC (1976): Heredity, Environment and Personality: A Study of 850 Sets of Twins. Austin: University of Texas Press.
13. Lytton H (1980): Parent-Child Interaction: The Socialization Process Observed in Twin and Singleton Families. New York: Plenum.
14. Martin NG, Eaves LJ (1977): The genetical analysis of covariance structure. Heredity 38: 79-95.
15. Martin NG, Wilson SR (1982): Bias in the estimation of heritability from truncated samples of twins. Behav Genet 12:467-472.
16. Mittler P (1970): Biological and social aspects of language development in twins. Dev Med Child Neurol 12:741-757.
17. Naylor H (1980): Reading disability and lateral asymmetry: an information-processing analysis. Psychol Bull 87:531-545.
18. Nie NH, Hull CH, Jenkins JG, Steinbrenner K, Bent DH (1975): Statistical Package for the Social Sciences, 2nd Ed. New York: McGraw-Hill.
19. O'Brien PJ, Hay DA (1983): Is rearing twins different? The development and needs of multiple birth children and their families from birth to school age. Proceedings of the Second National Child Development Conference, Australia.
20. Record RG, McKeown T, Edwards JH (1970): An investigation of the differences in measured intelligence between twins and single births. Ann Hum Genet 34:11-20.
21. Richman N, Stevenson J, Graham PJ (1982): Pre-school to School: A Behavioural Study. London: Academic Press.
22. Rutter M (1978): Prevalence and types of dyslexia. In Benton AL, Pearl D (eds): Dyslexia: An Appraisal of Current Knowledge. New York: Oxford UP, p 3-28.
23. Savage JF, Mooney JF (1979): Teaching Reading to Children with Special Needs. Boston: Allyn and Bacon.
24. Savic S (1980): How Twins Learn to Talk: A Study of the Speech Development of Twins from 1 to 3. New York: Academic Press.
25. Springer SP, Searleman A (1978): Hemispheric asymmetry of function in twins. In Nance WE, Allen G, Parisi P (eds): Twin Research: Part A. Psychology and Methodology. New York: Alan R. Liss, p 57-62.
26. Watts D, Lytton H (1981): Twinship as handicap: fact or fiction? In Gedda L, Parisi P, Nance WE (eds): Twin Research 3: Part B. Intelligence, Personality and Development. New York: Alan R. Liss, p 283-286.
27. Wilson RS (1977): Twins and siblings: concordance for school-age mental development. Child Dev 48:211-216.
28. Zazzo R (1978): Genesis and peculiarities of the personality of twins. In Nance WE, Allen G, Parisi P (eds): Twin Research: Part A. Psychology and Methodology. New York: Alan R. Liss, p 1-11.

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