ORIGINAL ARTICLE

Children born weighing less than 1701 g: visual and cognitive outcomes at 11–14 years

Terence Stephenson, Sharon Wright, Anna O'Connor, Alistair Fielder, Ann Johnson, Sonia Ratib, Michael Tobin

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See end of article for authors' affiliations

Correspondence to:
Professor Terence Stephenson, Centre for Reproduction and Early Life, Academic Division of Child Health, School of Human Development, University of Nottingham, Nottingham NG7 2UH, UK; terence.stephenson@nottingham.ac.uk

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Background and objective: Few studies of low birthweight children have explored the relationship between later visual morbidity and neuropsychological function. This study evaluated these outcomes using a geographically defined cohort.

Methods: Prospective study of retinopathy of prematurity (ROP) in infants born weighing <1701 g, undertaken in 1985–7. 254 of the survivors consented to ophthalmic examination at 10–13 years. Four children were severely disabled and could not complete the tests. 198 of the remaining agreed to neuropsychological assessment at 11–14 years (British Ability Scales II (BAS), Movement Assessment Battery (ABC), Neale Analysis of Reading Ability).

Results: At 10–13 years, 99/198 children had an adverse ophthalmic outcome (AOO) (reduced acuity n=48, myopia n=40, strabismus n=36, colour defect n=2, field defect n=1). There were no significant differences between children with AOO and those with a normal ophthalmic outcome with regard to sex, gestation, birth weight, neonatal cranial scan appearances and social class. 106/198 had ROP; 98 had mild ROP with no increased risk of AOO in later childhood. All eight children with severe ROP had an AOO in later childhood. Children with an AOO performed worse on the BAS, ABC and reading ability tests.

Conclusions: At age 10–13, 50% of children born <1701 g have an AOO. These children are not simply those with earlier gestations, lower birth weight or ROP. Children with AOO have a worse neuropsychological outcome. The next step is to determine whether there are visual interventions which can improve ophthalmic outcome and whether a better neuropsychological outcome follows.

Survivors of preterm birth are at increased risk of cognitive impairment^{1–9} and poor school performance.^{2 3 7 9 10} In particular, specific difficulties in reading, spelling, number skills and handwriting have been described. Low birthweight children are also at risk of later vision disorders, such as strabismus, defective visual acuity and myopia,^{11–18} whether or not they had retinopathy of prematurity (ROP).¹⁹ The relationship between disorders of vision and cognitive deficits is not well understood as the two areas of function have rarely been studied in detail and concurrently in the same children.²⁰ In low birthweight children, it is not known if vision and cognitive disorders have a common causal pathway or whether problems in the visual pathways impair specific areas of school performance.

We studied this relationship in a geographically defined cohort of low birthweight children to test the hypothesis that in school-aged children who were born with low birth weight, there is an association between neuropsychological outcome and visual morbidity, and that this association is independent of social and perinatal factors.

METHODS

Subjects

A geographically defined, prospective study of ROP was undertaken in 1985–7.²¹ Infants born to mothers resident in the East Midlands region in the UK, with birth weight <1701 g and surviving three weeks, were enrolled from five neonatal units in Nottingham, Derby and Leicester. This cohort of 505 infants (mean gestation 31.1 weeks; mean birth weight 1345 g) had ophthalmic examinations from 3 to 12 weeks of age and at 6 months corrected age. Of these, 248 developed ROP, of whom 4% had severe ROP (stage 3 or worse).

Tracing the subjects

Of the 505 infants, 29 had died, 5 had left the UK and 23 could not be traced. Two families were not contacted at their doctor's request. Sixteen families declined to participate and 176 did not give written consent despite repeated reminders (three postal and two telephone). Thus 254 families consented to ophthalmic examination, conducted by one orthoptist.¹⁹ However, four children were too disabled to undertake neuropsychological assessments. Of 250 families, 198 gave written informed consent to neuropsychological assessment (approximately one year after ophthalmic assessment) conducted by one psychologist. All investigators were masked to the child's perinatal history and original ROP status. We chose not to study a matched control group of term infants as we were principally interested in within-cohort analyses.

Assessment protocol

Ophthalmic investigation

The ophthalmic tests are described in detail elsewhere.¹⁹ In summary, these were: visual functions (logMAR distance and near acuity,^{22 23} contrast sensitivity, stereoacuity, perimetry, colour vision); strabismus (cover test and prism tests); and refractive state and eye dimensions. Corrected visual acuity was assessed using the child's own spectacles or a pinhole if refractive error had not been previously detected or acuity remained below 0.0 logMAR units even with glasses.

Abbreviations: ABC, Movement Assessment Battery for Children; BAS, British Ability Scales; GCA, general conceptual ability; ROP, retinopathy of prematurity

Cognitive ability

The overall measure of the British Ability Scales II (BAS II)²⁴ is the general conceptual ability (GCA) score with mean (SD) of 100 (15) in the normal population. The GCA score sums three clusters: verbal, non-verbal and spatial abilities. Individual BAS items have a mean of 50 (10). In addition, there are “diagnostic scales” which do not contribute towards the GCA score (eg speed of information processing).

Motor ability

The Movement Assessment Battery for Children (ABC)²⁵ tests dexterity, ball skills and balance. A score below the 5th percentile of the normal population is classified as a definite motor problem, and between 5th and 15th percentiles as borderline.

Reading ability

The Neale Analysis of Reading Ability—Revised is an oral test for children aged 6–12 years to assess accuracy, rate and comprehension.²⁶

Statistical methods

We calculated either the means and standard deviations or, for variables not normally distributed, medians and interquartile ranges (IQRs). All data were investigated for normality, by histograms, to determine whether parametric or non-parametric methods should be used. The unpaired t test was used for normally distributed variables and the Mann–Whitney U test for variables not normally distributed. χ^2 tests were performed on categorical data. When comparing more than two groups, one-way analysis of variance or the Kruskal–Wallis test was used for continuous data and the χ^2 test for categorical data. Multivariate linear regression was used to control for potential confounders. Testing was in all cases two-sided. We analysed all data using the statistics packages SPSS (version 8) and STATA (version 5).

RESULTS

Ophthalmic assessment was carried out between the ages of 10 and 13 years (mean 11 years, 6 months). Neuropsychological assessment was carried out between the ages of 11 and 14 years (mean 12 years, 8 months). Of the 198 children who had a neuropsychological assessment, 174 were white, 12 were Asian, 6 were black and 6 were mixed race. We did not find any significant differences between the 198 children assessed and the 307 not assessed with regard to birth weight, gestational age, sex, incidence of ROP or cranial ultrasound abnormalities (table 1). Parental occupation was not recorded at birth. Current social class of children not assessed was not derived because their parents declined consent to providing information.

Ophthalmic findings

Of the 198 children, 99 (50%) were classified as having an adverse ophthalmic outcome at 10–13 years.¹⁹ An adverse ophthalmic outcome was defined as corrected binocular visual acuity below the norm (6/6 Snellen, 20/20 in the USA or 0.0 logMAR units) (n = 48, 24%) or the presence of strabismus (n = 36, 18%), myopia (n = 40, 20%), colour vision defect (n = 2, 1%) or field defect (n = 1, 0.5%). Some children had more than one defect. These outcomes result in a referral to ophthalmic services in the UK. All children who had strabismus before 7 months corrected age still had strabismus at 12 years. Even those who had surgery still had some residual deviation. We found no statistically significant differences between the children with an adverse ophthalmic outcome and those with a normal ophthalmic outcome with regard to sex, gestational age,

Table 1 Comparison of the neonatal characteristics of children assessed and those who could not be assessed from the original cohort of 505

	Children assessed (n = 198)	Children not assessed (n = 307)	p Value
Sex			
Male	99 (50)	152 (49.5)	0.855 (χ^2 , 1 df)
Female	99 (50)	147 (47.9)	
Unknown	0	8 (2.6)	
Birth weight (g)			0.369 (Mann–Whitney)
Mean	1335.4	1351	
Number $\leq$ 1000 g	24 (12.1)	46 (15)	
Unknown	0	1	
Median	1377.5	1420	
IQR	1147.5, 1560	1137.5, 1580	
Gestational age (weeks)			0.086 (t test)
Mean (SD)	30.8 (3.04)	31.3 (3.01)	
Number $\leq$ 28 weeks	51 (25.8)	52 (16.9)	
Unknown	0	1	
Retinopathy of prematurity status			0.394 (χ^2 , 3 df)
None	92 (46.5)	165 (53.7)	
Stage 1	67 (33.8)	84 (27.4)	
Stage 2	31 (15.7)	46 (15)	
Stage 3/4	8 (4)	12 (3.9)	
Neonatal cranial ultrasound			0.136 (χ^2 , 2 df)
Abnormal	61 (30.8)	91 (29.6)	
Normal	58 (29.3)	69 (22.5)	
Not done	79 (39.9)	147 (47.9)	

birth weight, neonatal cranial ultrasound scan appearances and current social class (table 2).

Of the 198 children, 106 had ROP in the neonatal period. Unsurprisingly, children with ROP were smaller and less mature at birth (table 3). The presence or stage of ROP in the neonatal period, excluding the eight children with severe ROP, did not predict which children would have an adverse ophthalmic outcome at 10–13 years (table 2). On excluding these eight with stage 3/4 ROP, there was no longer a significant association between ROP status and adverse ophthalmic outcome ($p = 0.45$ rather than 0.013).

Cognitive findings

First, the cohort performed below average in almost all areas (table 4). However, children who had ROP in the neonatal period did *not* have lower BAS II scores overall 11–14 years later.

Second, we compared BAS II scores for children with and without an adverse ophthalmic outcome. There was an association between long-term ophthalmic outcome and performance on the BAS II in almost all areas (statistically significant for spatial ability, $p = 0.01$). Excluding the eight with stage 3/4 ROP (all had an adverse ophthalmic outcome), this association between adverse ophthalmic outcome and spatial ability remained strong ($p = 0.02$). Children with an adverse ophthalmic outcome performed significantly worse on both design recall and pattern construction within the spatial ability cluster ($p = 0.037$ and $p = 0.009$, respectively). Those with an adverse ophthalmic outcome performed worse on speed of information processing and in recall within the diagnostic scales.

Third, the results of multivariate linear regression showed that after controlling for ROP stage, gestational age, birth weight, cranial ultrasound, social class and sex, the BAS scores (table 5) were still associated with adverse ophthalmic outcome. The associations were, therefore, independent of these

Table 2 Comparison of the characteristics of children with a normal or an adverse ophthalmic outcome at mean age 11 years and 6 months

	Normal ophthalmic outcome (n = 99)	Adverse ophthalmic outcome (n = 99)	p Value
Sex			
Male	50 (50.5)	49 (49.5)	0.887 (χ^2 , 1 df)
Female	49 (49.5)	50 (50.5)	
Age of neuropsychological assessment			
Mean (SD)	12.77 (0.58)	12.67 (0.62)	0.240 (t test)
Birth weight (g)			
Mean	1363.3	1307.5	0.145 (Mann-Whitney)
Number $\leq$ 1000 g	10 (10.1)	14 (14.1)	
Median	1450	1300	
IQR	1150, 1560	1140, 1540	
Gestational age (weeks)			
Mean (SD)	31.1 (2.79)	30.5 (3.26)	0.169 (t test)
Number $\leq$ 28 weeks	21 (21.2)	30 (30.3)	
Retinopathy of prematurity status			
None	49 (49.5)	43 (43.4)	0.013 (Fisher's exact test)
Stage 1	37 (37.4)	30 (30.3)	
Stage 2	13 (13.1)	18 (18.2)	
Stage 3 or 4	0	8 (8.1)	
Neonatal cranial ultrasound			
Abnormal	34 (30.8)	27 (27.3)	0.488 (χ^2 , 2 df)
Normal	26 (29.3)	32 (32.3)	
Not done	39 (39.9)	40 (40.4)	
Social class (mother)			
1 and 2	23 (23.2)	16 (16.2)	0.283 (χ^2 , 3 df)
3	32 (32.3)	37 (37.4)	
4 and 5	20 (20.2)	28 (28.3)	
Unknown	24 (24.2)	18 (18.2)	
Social class (father)			
1 and 2	27 (27.3)	28 (28.3)	0.444 (χ^2 , 3df)
3	28 (28.3)	37 (37.4)	
4 and 5	16 (1.2)	11 (11.1)	
Unknown	28 (28.3)	23 (23.2)	

potential confounding factors, insofar as we were able to test them. A cerebral scan was not done for 39 (39.9%) of the children with normal ophthalmic outcome and 40 (40.4%) with adverse ophthalmic outcome. (Scanning was not routinely done in the East Midlands in 1985–7.) Maternal social class data were not available for 24 (24.2%) of the children with normal ophthalmic outcome and 18 (18.2%) with adverse ophthalmic outcome because the parent declined this information. Oxygen dependence at 28 or 36 weeks was not recorded in the original dataset.

Fourth, the presence of strabismus, abnormal three-dimensional vision (stereopsis) and decreased visual acuity with

correction were all significantly associated with poor spatial ability (see table 6 for the p values). Binocular contrast sensitivity with correction and refractive error were not associated with BAS II spatial ability scores (data not shown).

Fifth, neonatal ROP status was examined in relation to BAS II performance (table 7). Only 8 (4%) of the cohort had severe ROP (stage 3 or above), none had stage 5 ROP (total retinal detachment), and none were registered blind. Those children with ROP stage 3 or 4 achieved lower BAS II GCA and cluster scores. There was no systematic trend in scores between those who never had ROP and those with stages 1 and 2.

Reading ability

Children with an adverse ophthalmic outcome performed less well in all three areas of reading ability than those with normal ophthalmic outcome (up to 0.3 SD worse), but this difference was not statistically significant (data not shown).

Movement ability

In movement ability tests, 113 (57%) of the cohort scored below the 15th percentile for the normal population (data not shown). Children with an adverse ophthalmic outcome had worse median scores in all four areas of the ABC (statistically significant for ball skills, $p = 0.01$).

DISCUSSION

Our geographical cohort study is unusual because it combines neonatal and long-term ophthalmic data with later neuropsychological data. The return rate of 254 children examined at 11–14 years out of 505 at 3–12 weeks is a criticism, but it follows 10 years of no contact. Other follow-up studies from preterm to teenage show comparable rates.²⁸ There were no statistically significant differences in gestational age, birth weight and incidence of ROP between the 254 tested and the 222 children not tested but alive.¹⁹ We suggest therefore that follow-up of these 254 children over a long period is both valuable and representative of the original cohort. Sensitivity analysis showed that the adverse ophthalmic outcome rate in those not followed up would have to be 3/222 (1.4%) to overturn the statistical significance of the study cohort rate of adverse ophthalmic outcome (50%).

An adverse ophthalmic outcome at age 10–13 years was found in 99/198 children examined (50%); 18% had strabismus, consistent with other studies.^{29–30} Adverse ophthalmic outcome was not simply a product of being born more preterm or being born more socially deprived (table 2). This confirms the findings of Powls *et al*¹⁷ but they were unable to exclude the possible confounder of neonatal ROP as their very low birthweight cohort were not screened ophthalmologically. In our study, 106 children had ROP in the neonatal period (table 3). ROP still occurs,³¹ but stage 1 and 2 ROP do not predict ophthalmic problems 10–13 years later (table 2).

Only one other long-term, follow-up, geographical study of ophthalmic and cognitive outcomes in a cohort of preterm infants has been published.²⁰ In that study, 279 children out of a potential 382 born before 32 weeks' gestation in Liverpool during 1991–2 and attending mainstream schools (thus excluding children with major disability) were re-examined at seven years. The children's original ROP status and neonatal cranial ultrasound scan data were extracted retrospectively from the clinical case records of the eight hospitals involved. As in our study, mothers not resident in the defined geographical region at the time of the infant's birth were excluded. A total of 143 infants weighed less than 1500 g at birth, and of these 115 had been examined for ROP. Thirty-one were recorded as having had stage 1, 20 stage 2 and 8 stage 3 ROP. Infants over 1500 g birth weight were not routinely screened for ROP. At seven years, preterm infants were considerably more likely to wear glasses, to have poor visual acuity, reduced

Table 3 Comparison of birth weight and gestational age between no retinopathy of prematurity (ROP) and ROP groups

	No ROP (n = 92)	ROP (n = 106)	p Value
Birth weight (g)			
Median	1500	1190	<0.001 Mann-Whitney U test
Interquartile range	1320, 1600	1048, 1485	
Gestational age (weeks)			
Mean	32.45	29.43	<0.001 t test
SD	2.67	2.64	
			Mean difference (95% CI) 3.01 (2.27 to 3.76)

Table 4 British Ability Scale (BAS) II scores of children with a normal or an adverse ophthalmic outcome, (mean age 12 years 8 months)

BAS II component	All children (n = 198) Mean (SD)	Normal ophthalmic outcome (n = 99) Mean (SD)	Adverse ophthalmic outcome (n = 99) Mean (SD)	Comparing adverse and normal outcome (p value)	Children with retinopathy of prematurity in newborn period (n = 106) Mean (SD)
General conceptual ability standard score	93.0 (18.2)	95.7 (17.6)	90.4 (18.5)	0.04	94.1 (19.1)
Verbal reasoning cluster	96.5 (17.2)	98.2 (16.4)	94.8 (17.9)	0.172	98.2 (17.4)
Word definition	45.4 (12.4)	46.7 (11.9)	44.1 (12.8)	0.131	46.6 (12.9)
Verbal similarities	52 (46, 56)*	53 (46, 56)*	51 (45, 56)*	0.399†	53 (47, 57)*
Non-verbal reasoning cluster	90.2 (17.8)	92.3 (16.8)	88.2 (18.7)	0.099	91.5 (17.1)
Matrices	44.0 (10.2)	44.5 (9.3)	43.6 (11)	0.518	44.6 (10.3)
Quantitative reasoning	45.2 (12.3)	46.6 (12.8)	43.8 (11.5)	0.101	45.6 (12.7)
Spatial ability cluster	96.0 (17.4)	99.2 (17)	92.8 (17.4)	0.01	96.2 (18.4)
Recall of designs	47.6 (12.5)	49.5 (12.5)	45.8 (12.3)	0.037	48.1 (12.3)
Pattern construction	48.3 (10)	50.1 (9.3)	46.4 (10.4)	0.009	47.9 (11.2)
Diagnostic scales					
Speed of information processing	51.4 (13.6)	53.8 (12.6)	49 (14.1)	0.012	52 (14.1)
Recall of digits forward	49.5 (11.5)	51.1 (9.6)	48 (11.8)	0.055	51.2 (11)
Recall of digits backwards	44.5 (36, 51)	46 (37, 52)*	43 (32, 49)*	0.016†	47 (36, 54)*
Recall of pictures	50.6 (10.2)	51.7 (9.6)	49.6 (10.8)	0.157	50.5 (11.1)
Recall of objects—immediate verbal	49.3 (12)	51 (10.9)	47.6 (12.8)	0.044	50.2 (12.4)
Recall of objects—delayed verbal	53 (44, 60)*	53 (48, 60)*	52 (39, 60)*	0.182†	53 (43, 60)*
Recall of objects—immediate spatial	49 (43, 53)*	49 (43, 53)*	49 (41, 53)*	0.869†	49 (43, 53)*
Recall of objects—delayed spatial	49 (44, 53)*	49 (44, 53)*	49 (44, 53)*	0.424†	49 (44, 53)*

*Median and interquartile range; †Mann-Whitney U test.

stereopsis and strabismus than term controls. The strongest associations in performance were between visual outcome and motor impairment. Ophthalmic impairments were considerably related to poorer scores on visual-motor integration testing, the Movement ABC and Wechsler intelligence quotient (IQ) tests, with the exception of verbal IQ. Ophthalmic impairments were not significantly related to neonatal cranial ultrasound appearances. Stage 3 retinopathy was related to poorer subsequent acuity but not ROP stage 1 or 2. Our findings at secondary school (11–14 years) are therefore entirely consistent with this previous follow-up in primary school at seven years. This adds weight to the general conclusions of both studies, particularly as our findings come from a different geographical cohort and time period with different investigators using different methods. The Liverpool cohort was selected by gestation and geographical area whereas ours was selected by birth weight and geographical area. Moreover, the ROP data used in our analysis were collected prospectively by a single examiner²¹ and we did not routinely exclude children with major disability from ophthalmic follow-up (although four were unable to perform the cognitive tests).

Our cohort had lower cognitive attainments at school age consistent with previous research.^{4, 32–36} Our motor findings are comparable with another preterm cohort from a similar era.³⁷ Roth *et al*,³⁸ reporting outcomes at 14–15 years in a cohort born <33 weeks' gestation between 1979 and 1982, also found

reading age was lower compared with standardised norms, but they had no detailed ophthalmic outcome data.

Our most striking finding was that cognitive attainment of low birthweight children at age 11–14 was more closely associated with their current visual status than with retinopathy in the neonatal period. Those with an adverse ophthalmic outcome scored, on average, 6.4 points less on spatial abilities (table 4). It is biologically plausible that the spatial ability cluster of the BAS would be strongly associated with an adverse visual outcome. The association between BAS II scores and ophthalmic outcome remained after controlling for ROP, gestation, birth weight, cranial ultrasound, social class and

Table 6 Association between performance on the British Ability Scale (BAS) II spatial ability cluster and measures of specific ophthalmic functions

	BAS II spatial score			p Value
Strabismus	n	Mean	SD	
Yes	36	88.3	17.7	0.003 (unpaired t test)
No	162	97.7	16.9	
Stereopsis	n	Median	IQR	
Normal (TNO ≤60)	136	98	88, 111	0.001 (Kruskal-Wallis test)
Slightly reduced (TNO >60 but <480)	29	99	83, 107	
Moderately reduced (TNO ≥480)	33	86	69, 95	
Binocular distance acuity with correction (log units)	n	Median	IQR	
Normal (≤0.0)	151	98	87, 110	0.007 (Kruskal-Wallis test)
Slightly reduced (0.0–0.3)	43	95	82, 105	
Moderately reduced (>0.3)	4	67	55.3, 81.8	

IQR, interquartile range.

TNO (Netherlands Organisation for Applied Scientific Research) test for stereoscopic depth sense uses images of two colours, representing the two retinal views of a three-dimensional scene, presented to each eye separately using coloured spectacles. Stereoscopic vision can be quantified over the range 15–1980 s of arc.²⁷

Binocular acuity with correction: 0.0 is equivalent to Snellen 6/6 (normal) and 1.0 is equivalent to 6/60 (very poor vision).

Table 5 Results of regression models for significant outcomes only

Outcome	Adverse ophthalmic regression coefficient (SE)	p Value
General conceptual ability standard score	9.26 (0.03)	0.028
Verbal standard score	9.78 (3.78)	0.012
Word definition T score	7.9 (2.8)	0.006
Recall of objects—delayed verbal	8.14 (2.9)	0.006
Spatial standard score	8.93 (4.16)	0.035
Recall of objects—immediate verbal	9.74 (2.88)	0.001

Table 7 British Ability Scale (BAS) II performance in association with neonatal retinopathy of prematurity (ROP) status

Neonatal ROP status	Number tested	General conceptual ability standard score		Spatial ability	
		Mean (SD)	No. (%) with score <85*	Mean (SD)	No. (%) with score <85*
All children	198	93.0 (18.2)	56 (28.3)	96 (17.4)	49 (25)
ROP status					
None	92	92 (17.2)	28 (30.4)	95.9 (16.4)	20 (21.7)
Stage 1	67	96.1 (18.9)	17 (25.4)	98.4 (17.9)	17 (25.4)
Stage 2	31	93.1 (16.6)	6 (19.4)	93.6 (17.5)	8 (25.8)
Stage 3/4	8	79.3 (24.4)	5 (62.5)	84.4 (22.8)	4 (50.0)
p Value (one-way analysis of variance)		0.078		0.174	

*More than 1 SD below mean.

sex. We do not have data on postnatal dexamethasone usage, which could affect both cognitive and visual outcomes by impairing grey matter growth.³⁹ However, if postnatal steroids explained the association of BAS II scores and an adverse ophthalmic outcome, we would expect gestation and birth weight to be significant confounders, which they were not, as steroids were most frequently used in such infants.

Strabismus, abnormal three-dimensional vision (stereopsis) and decreased corrected visual acuity were associated with BAS II spatial ability score (table 6). Strabismus can also be due to cerebral palsy and neuromuscular impairments rather than ocular damage alone. However, irrespective of underlying mechanism, an adverse ophthalmic outcome results from lack of binocular functions plus amblyopia (reduced acuity).

It is sometimes not appreciated that a child can have reduced acuity without being myopic. The observed association of BAS II spatial ability with reduced acuity must be via visual pathway impairments rather than the refractory apparatus (cornea, lens, eyeball) because corrected visual acuity was assessed. Acuity was tested with spectacles (43/198 children wore glasses) so the reduced acuity was not due to myopia. Myopia was not associated with poor spatial ability. Finally, previous mild ROP does not explain these later problems with spatial ability (table 7).

Does the adverse ophthalmic outcome cause the poorer cognitive performance or are these associated because of damage to both the visual pathways and the cognitive centres? If the causal explanation is correct, it is possible that early identification of subtle visual disturbance may allow ophthalmic and educational intervention, concentrating on improving spatial skills. Against simple association is that visual problems at secondary school age are not explained by greater prematurity, lower birth weight or more abnormal neonatal ultrasound scan appearances (table 2), all factors in poor cognitive outcome.^{33–40} Similarly, when Cooke *et al*²⁰ compared infants with birth weights above and below 1500 g, there were no significant differences in visual outcomes at seven year follow-up. Furthermore, in that study, strabismus, poor visual acuity, absent stereopsis and low contrast sensitivity were also unrelated to the maximum extent of periventricular haemorrhage or periventricular leukomalacia on neonatal cranial ultrasound scan.²⁰ However, the lack of a relationship between neonatal ultrasound scan appearances and the more subtle visual problems which we and Cooke *et al*²⁰ describe do not exclude the possibility of a common hypoxic/ischaemic insult. Lower birth weight or major cranial ultrasound abnormalities^{37–40} can certainly predict major disabilities.^{32–34–41–45} Marked visual disability can also be predicted from cranial ultrasound abnormalities.^{46–50}

However, in contrast to major disabilities, ultrasound prediction of learning difficulties, possibly due to less severe diffuse white matter damage,^{51–53} is less precise.⁵⁴ The sensitivity

of ultrasound to detect small areas of white matter abnormality is relatively poor.^{55–57} Furthermore, the effects of hypoxia/ischaemia may not be apparent on imaging until 32 weeks postconceptual age^{58–59} and may cause reduced grey matter volume⁶⁰ which ultrasound cannot easily measure.

All but one of the subscales of the BAS II in which there were significant differences between the children with adverse and normal ophthalmic outcome involve a *timed* component. The education system places a great emphasis on timed procedures, such as school examinations. The potential additive effect of ophthalmic problems and underachieving in timed tasks might be substantial. Coupled with motor problems (which could cause poor handwriting), reduced reading comprehension and behaviour disorders,³² there are several additive factors which could lead to poor educational performance in ex-preterm children without overt disability.

CONCLUSIONS

The main finding of the present study is that half of children born at less than 1701 g birth weight have an adverse ophthalmic outcome associated with poorer cognitive outcome

What is already known on this topic

- At 7 years of age, the survivors of preterm birth are at increased risk of later vision disorders, such as strabismus, defective visual acuity and myopia.
- Ophthalmic impairments at 7 years are strongly related to poorer scores on visuomotor integration testing, the Movement Assessment Battery for Children and Wechsler IQ tests. Stage 3 retinopathy is related to poorer subsequent acuity but not stage 1 or 2.

What this study adds

- Half of a geographical cohort of children born weighing less than 1701 g and followed to 11–14 years had an adverse ophthalmic outcome (reduced visual acuity, strabismus, myopia, colour vision defect or field defect), and this was associated with poorer cognitive outcome.
- Neither poor cognitive nor poor ophthalmic outcome at 11–14 years are associated with previous stage 1 or 2 retinopathy of prematurity. Rather, poor cognitive attainment is associated with adverse visual outcomes which manifest *after* the perinatal period.

at 11–14 years. Neither outcome is due to mild ROP. Rather, poor cognitive attainment is associated with adverse visual outcomes which manifest *after* the perinatal period. To determine causality, the effect of early detection and management of visual defects on later cognitive function could be studied. Low birthweight children should undergo early, regular visual assessment to detect visual impairment and enable intervention.

Authors' affiliations

Terence Stephenson, Centre for Reproduction and Early Life, Academic Division of Child Health, School of Human Development, University of Nottingham, Nottingham, UK

Sharon Wright, Anna O'Connor, Academic Division of Child Health, School of Human Development, University of Nottingham, UK

Alistair Fielder, Department of Optometry and Visual Science, City University, London, UK

Ann Johnson, National Perinatal Epidemiology Unit, University of Oxford, Oxford, UK

Sonia Ratib, Trent Institute for Health Sciences Research, University of Nottingham, Nottingham, UK

Michael Tobin, School of Education, University of Birmingham, Birmingham, UK

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