The New Survivors: The longer term cognitive, scholastic and motor outcomes of a total Scottish population of surviving very low birthweight infants

Volume 1

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THESIS DECLARATION.

I declare this thesis and the research upon which it is based to be my own work having been completed within the normal terms of supervision (by Dr. I.W.R. Bushnell) in the Faculty of Social Science in the University of Glasgow, Scotland. The majority of the psychological assessment was undertaken by myself. Two psychology graduates were recruited to assist with the rest of the data collection. I was responsible (a) for training these assistant psychologists in the standardised presentation of the assessment instruments and (b) for quality assurance – supervising and monitoring their performance throughout the data collection phase. The data were coded and the dataset compiled by myself, with the ownership of the psychological dataset being mine.

I testify that this thesis has not been accepted in any previous application for a degree, that all verbatim references have been distinguished by quotation marks and that all sources of information have been specifically acknowledged.

Alastair Eaton Hall

18th November, 2000

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Dedication

This thesis is dedicated to the memory of my uncle
Ernest H Eaton M.A. (Oxon.) of Chania, Crete (1908-1980).

Nec Manus, Nisi Intellectus, Sibi Permissus, Multum Valent

(Bacon)

"Neither hand nor intellect, left each to itself, is worth much."

Contents

Volume 1

Abstract

Chapter 1 Low Birthweight Research - An Introduction 1

1.1 A brief history 1

1.2 Early epidemiological research 1

1.3 Definitions of prematurity in Biblical times 2
1.3.1 Attempts to define prematurity in the late 19th and early 20th centuries 3
1.3.2 Current definitions of low birthweight, very low birthweight and extremely low birthweight and of prematurity 3
1.3.3 Difficulties in accurately assessing gestational age 3
1.3.3.1 Birthweight versus gestational age as the basis for cohort membership in follow up studies 4

1.4 Epidemiology of low birthweight 5
1.4.1 Social class 5
1.4.2 Ethnic origin 7
1.4.3 Maternal factors 8
1.4.3.1 Maternal illnesses 8
1.4.3.1.1 Pregnancy induced hypertension 8
1.4.3.1.2 Sexually transmitted diseases 8
1.4.3.2 Marital Status 9
1.4.4 Smoking 9
1.4.5 Drug and alcohol abuse 10
1.4.6 Maternal age 11
1.4.7 Residential proximity to industrial sites 12
1.4.8 Short interpregnancy interval 13
1.4.9 Employment involving use of video display unit 13
1.4.10 In vitro fertilisation 13
1.4.11 Work stress 14
1.4.12 Psychosocial stress 15
1.4.13 Summary and conclusion 15

Chapter 1 cont.

1.5 Difficulties in evaluating perinatal intensive care procedures dating from the late 1960s 16

1.6 Evidence for the efficacy of perinatal intensive care from the 1960s 17

1.7 Early advances in neonatal intensive care in the late 1970s 18

1.8 Further improvements in the survival of VLBW infants resulted from the provision of neonatal care units 18

1.9 Advances in neonatal care of VLBW infants of the last decade 19
1.9.1 Surfactant treatment 20
1.9.2 Extra-corporeal membrane oxygenation 20
1.9.3 Inhaled nitric oxide 21
1.9.4 High frequency oscillation ventilation 22
1.9.5 Prophylaxis against group B streptococcal infection 23
1.9.6 Summary of recent advances in the care of very low birthweight neonates 23

1.10 Morbidity in VLBW infants 24

1.11 Neonatal intensive care as measured by prevalence of cerebral palsy in VLBW infants 25

1.12 Minor neurological dysfunction and longer-term outcomes 26

Chapter 2 Low Birthweight Research – Cognitive Development, School Attainment and Neuromotor Competence: A Review of the Literature

Section 1 Context, Scope and Theoretical Considerations 27
2.1 Scope of the review of the literature on low birthweight research 27
2.1.1 Investigations of the psychological domains of development in low birthweight children 27

2.2 Low birthweight research and psychological theories of development 28
2.2.1 Psychological theories of development in the context of VLBW research 28
2.2.2 Medical versus psychological approaches to VLBW research 29
2.2.3 Piaget's theory of logical development in childhood 30
2.2.1.1 The 'stage' nature of Piaget's theory 31

Chapter 2 cont.

2.2.3.1.1 The sensory motor stage 32
2.2.3.1.1.1 Sensory motor substages 32
2.2.3.1.2 The period of pre operations (2 – 7 years) 34
2.2.3.1.3 Concrete operational thought 35
2.2.3.1.4 Formal operation thought 35
2.2.3.2 The relationship of Piagetian developmental theory and VLBW research 36

2.3 Origins of the literature on the longer term outcomes of the "new survivors" of neonatal intensive care 39

2.4 Very low birthweight and major sequelae 39
2.4.1 Bias in the reporting of mortality statistics 42

2.5 The "new survivors" of neonatal intensive care 42
2.5.1 Further attempts to clarify the question of major sequelae 43
2.5.2 The age-deterioration hypothesis 44

2.6 Shift of research focus from major sequelae to lesser morbidities 46

Section 2 Cognitive Ability and Scholastic Attainment 46
2.7 School age cognitive outcomes of VLBW children 46
2.7.1 The evolution of studies investigating school age outcomes 46
2.7.1.1 General conceptual ability 47

2.8 Hospital centre based studies versus population based studies 47
2.8.1 Contributions to the literature from hospital centre and unit studies 48
2.8.1.1 The Nottingham Study 49
2.8.1.2 The Finnish Study 50
2.8.1.3 The Wolverhampton Study 50
2.8.1.4 The Liverpool Maternity Hospital Study 52
2.8.1.4.1 The six year follow up study 52
2.8.1.4.2 The eight year follow up study 54
2.8.1.4.3 The 12 year follow up study 54

Chapter 2 cont.

2.8.1.5 Assessment of increasingly discrete measures of cognitive functioning and scholastic 56
2.8.1.5.1 Assessment of executive function 56
2.8.1.6 Assessment of cognitive functioning in the present study 58
2.8.2 Contributions to the literature from population based studies 58
2.8.2.1 The Canadian regional cohort (Ontario) study 59
2.8.2.2 The New Zealand Study 60
2.8.2.2.1 Methodological issues relating to the New Zealand study 60
2.8.2.3 Project on Preterm and Small for Gestation Age infants (POPS) in the Netherlands 61
2.8.2.3.1 The five year follow up 61
2.8.2.3.2 The nine year follow up 62
2.8.2.3.3 Documenting the characteristics of those who drop out 63
2.8.2.3.3.1 Characteristics of those who dropped out in the Netherlands study 63
2.8.2.3.4 Methodological issues relating to the Netherlands study 63
2.8.2.4 The Mersey Region study 64
2.8.2.4.1 The pre school follow up 64
2.8.2.4.2 The eight year follow up 64
2.8.2.4.2.1 Cognitive ability and reading attainment at eight years of age 65
2.8.2.5 Assessment of cognitive functioning as a profile of skills (The Bavarian Study) 66
2.8.2.6 Assessment of cognitive functioning in the present study 67
2.8.3 Scope for comparison of the findings of the Scottish Low Birthweight Study with those of other population based studies of VLBW children 69

2.9 First set of hypotheses (cognitive ability and scholastic attainment) 70

Section 3 Neuromotor Functioning 73
2.10 The prevalence of major neuromotor disorders in VLBW population 73

2.11 School age motor outcomes of VLBW children 73
2.11.1 Contributions to the literature from hospital centre and unit studies 73
2.11.1.1 The Finnish Study 74
2.11.1.2 The Liverpool Maternity Hospital Study 75
2.11.1.2.1 The six year follow up study 75
2.11.1.2.2 The eight year follow up study 76
2.11.1.2.3 The 12 to 13 year follow up study 77
2.11.1.3 The Hammersmith Hospital Study 78

Chapter 2 cont.

2.11.1.3.1 Possible bias in the Hammersmith Hospital Study 79
2.11.1.4 Difficulties in comparing the findings of studies that have employed the TOMI or Movement ABC 80
2.11.2 Contributions to the literature from population based studies 80
2.11.2.1 The Mersey Region Study – the eight year follow up 81
2.11.2.2 The British Columbia Study – the nine year follow up 81

2.12 The relationship between neuromotor competence and cognitive ability and education attainment 83
2.12.1 Do perceptual motor problems ever occur in isolation? 83
2.12.2 The relationship between the extent of perceptual motor difficulties and contemporaneous problems in other developmental domains 84

2.13 Second set of hypotheses (motor competence and neurological functioning 85

Section 4 Additional Areas of Investigation 87
2.14 Differential effect of birthweight/preterm birth and small for gestational age on survival and postnatal development 87
2.14.1 Small for gestational age versus appropriate for gestational age within different development domains 88
2.14.2 Early studies of the differential effects of SGA and AGA in VLBW infants 89
2.14.2.1 Methodological flaws of early studies of the differential effects of SGA and AGA in VLBW infants 89
2.14.3 More recent studies of the differential effects of SGA and AGA on the outcomes of VLBW infants 89
2.14.3.1 Methodological issues relating to more recent studies of SGA and AGA VLBW infants 89
2.14.3.1.1 Difference in criteria for classifying infants as SGA 90
2.14.3.1.2 Definition of SGA employed in the present study 90
2.14.4 Differential effects of preterm birth and small for gestational age on cognitive development – The Mersey Region Study 90
2.14.1 SGA as a continuous variable in the Mersey Region Study 91
2.14.5 Issues relating to the criteria for matching comparison children 92
2.14.5.1 AGA comparison children in the Scottish Low Birthweight Study 92
2.14.5.2 Studies that have matched AGA comparison children by birthweight and by gestational age 93

Chapter 2 cont.

2.14.5.2.1 The Bavarian Study 93
2.14.6 Small for gestational age versus appropriate for gestational age on tests of neuromotor functioning 95
2.14.6.1 Investigation of the effects of SGA versus AGA on neuromotor functioning in the present study 96

2.15 Gender differences 96
2.15.1 Gender differences in survival and major sequelae 96
2.15.2 Gender differences in cognitive ability and scholastic attainment 98
2.15.3 Gender differences in neuromotor functioning 99

2.16 The gradient model of the relationship between birthweight and levels of functioning 101

2.17 Third set of hypotheses (SGA versus AGA, gender and gradient effect) 102

Chapter 3 Low Birthweight Research – Methodological Issues 104

3.1 Outcome is not simply a measure of medical intervention 104

3.2 Follow-up and serial follow-up studies of VLBW infants 104

3.3 Methodological issues of importance in follow-up studies 105
3.3.1 Minimising attrition rates 105
3.3.2 Bias in serial follow-up studies 106
3.3.2.1 Selection of the inception cohort 106
3.3.2.1.1 Referral bias 106
3.3.2.1.2 Selection bias 108
3.3.2.1.3 Sociodemographic bias 108
3.3.2.1.4 Control group bias 109
3.3.2.2 Bias affecting investigators, instruments and methods of data collection 110
3.3.2.2.1 Expectation bias 110
3.3.2.2.2 Exposure suspicion bias 110
3.3.2.2.3 Diagnostic suspicion bias 110

Chapter 3 cont.

3.3.2.2.4 Unacceptability bias 110
3.3.2.2.5 Time course bias 111
3.3.2.3. Analysis and interpretation bias 111
3.3.2.3.1 Correction for prematurity bias 111
3.3.2.3.2 Data analysis bias 111
3.3.2.3.3 Interpretation bias 112
3.3.3. Conclusion regarding the issue of bias in follow up studies 112

3.4 Lack of progress in unifying study design and methods of reporting 113
3.5 Mortality is not an unequivocal outcome measure 113
3.5.1. Mortality data should include infants who are dead at delivery 113
3.5.2 Mortality data should include postneonatal deaths 114
3.5.3 Registration of mortality is influenced by the current lowest limit of viability 114

3.6 Problems associated with a lack of uniformity in the use of terminology on morbidity 115

3.7 Methodological issues – concluding remarks 117

Chapter 4 The Scottish Low Birthweight Study - Methodology 119

4.1 The Population Base 119
4.1.1 The study cohort as presently defined 119
4.1.2 Changes to the Scottish Low Birthweight Study cohort 119
4.1.3 The inception cohort 120
4.1.4 The study group at two years of age 121
4.1.5 The nature of impairments 123
4.1.6 The study group at four years of age 123
4.1.7 The study group at eight years of age 126

4.2 Study design and implementation 127
4.2.1 Stages of development of design and implementation 127
4.2.2 The Scottish Low Birthweight Study Group 128
4.2.2.1 Study personnel involved at the eight year follow up 128
4.2.2.2 The role of the author 128

Chapter 4 cont.

4.2.3 Generation of research questions 129
4.2.4 Study design 130
4.2.5 Method 130
4.2.5.1 Permission to undertake the study 130
4.2.5.2 Identification of index and comparison children 130
4.2.5.2.1 Identification of the index children 130
4.2.5.2.2 Identification of the comparison children 131
4.2.5.3 Procedure for gaining parental consent 131
4.2.5.4 Organisation of data collection 131
4.2.6 The test protocol 132
4.2.6.1 Motor functioning 132
4.2.6.2 Cognitive ability 136
4.2.6.3 Neurological status 138
4.2.6.4 Self perception 140
4.2.7 Training of the research assistants 141
4.2.7.1 Interobserver variation 141
4.2.8 Arrangement of school visit 142
4.2.9 Characteristics of testing environment within the schools 142
4.2.10 Administration of the tests 143
4.2.11 Coding of the data 143
4.2.12 Data entry 143
4.2.13 Statistical analysis 143

Chapter 5 Low Birthweight Research - Results 145

Section 1 Illustrative Characterisation of the Index Group and, where possible, the Comparison Group 145
5.1.1. Description of index and comparison groups 145
5.1.1.1 Birthweight distributions 145
5.1.1.2. Gender differences in mean birthweights 146
5.1.1.3 Birthweight distributions by birthweight groupings 147
5.1.1.3.1 Mean birthweights and birthweight distributions for the <1000g group 147
5.1.1.3.2 Gender differences in mean birthweights for index children (<1000g) 148
5.1.1.3.3 Mean birthweights and birthweight distributions for the 1000-1499g group 149

Chapter 5 cont.

5.1.1.3.4 Gender differences in mean birthweights for index children (1000-1499g) 149
5.1.2 Gestational age distribution 150
5.1.2.1 Gender differences in mean gestational ages 151
5.1.2.2 Gestational age distributions by birthweight groupings 152
5.1.2.2.1 Mean gestational ages and gestational age distributions for the <1000g group 152
5.1.2.2.2 Gender differences in mean gestational ages 153
5.1.2.2.3 Mean gestational ages and gestational age distributions for the 1000-1499g group 154
5.1.2.2.4 Gender differences in mean gestational ages 155
5.1.3 Age distributions 156
5.1.3.1 Age distribution for index group at time of assessment 156
5.1.3.2 Age distribution for comparison group at time of assessment 157
5.1.4 Small for gestational age status of the index and comparison groups 158
5.1.5 Socio demographic factors 159

Section 2 Assessment of Cognitive Functioning and Educational Attainment 160
5.2.1 Cognitive functioning – Index children versus comparison children 160
5.2.1.1 Distribution of IQ (British Ability Scales) 160
5.2.2 Comparison of scores on cognitive subskills 162
5.2.3 Comparison of general IQ, verbal IQ and visual IQ composites 163
5.2.4 Comparison of scores of educational attainment 164
5.2.5 The relationship between cognitive and scholastic measures 165
5.2.5.1 The influence of IQ on poor performance on measures of scholastic attainment 166
5.2.5.1.1 Number skills 166
5.2.5.1.2 Reading skills 167

Section 3 Comparison of Children who were Small for gestational Age (SQA) and children who were Appropriate Birthweight for Gestation Age (AGA) 168
5.3.1 General cognitive ability SGA versus AGA 168
5.3.2 Comparison of scores on cognitive subskills by SGA/AGA status 170
5.3.3 Comparison of verbal and visual composite IQ scores by SGA/AGA status 171
5.3.4 Comparison of scholastic attainment by SGA/AGA status 172
5.3.4.1 Comparison of mean Word Reading scores (BAS) and mean Number Skills scores (BAS) and numbers of children functioning <10th percentile by SGA/AGA status – index and comparison groups 172

Chapter 5 cont.

Section 4 Comparison of Index and Control Groups by Gender 175
5.4.1 Gender differences in cognitive ability 175
5.4.2 Comparison of scores on cognitive subskills by gender 177
5.4.3 Comparison of verbal and visual composite scores by gender 177
5.4.4 Comparison of scholastic attainment by gender 178
5.4.4.3 Comparison of mean Word Reading score (BAS) and mean Number Skills scores (BAS) and numbers of children functioning <10th percentile by gender – index and comparison groups 178

Section 5 Comparison of Index and Control Groups by Birthweight Groupings: <1000g and 1000g-1499g 180
5.5.1 Characteristics of the index and comparison groups by birthweight groupings 180
5.5.2 Comparison of score of cognitive ability and educational attainment by birthweight groupings 181
5.5.3 The influence of IQ on poor performance on measures of scholastic attainment 186
5.5.3.1 Number skills 187
5.5.3.2 Reading skills 188

Section 6 Assessment of Motor Competence and Neurological Functioning 189
5.6.1 Motor competence 189
5.6.1.1 Movement Assessment Battery for Children – index children versus comparison children 189
5.6.2.1 Neurological functioning – index children versus comparison children 191

Section 7 Comparison of Children who were Small for Gestational Age (SGA) and Children who were Appropriate Birthweight for Gestational AGE (AGA) on tests of Neuromotor Functioning. 194
5.7.1 Motor competence 194
5.7.1.1 Performance on the Movement Assessment Battery for Children by SGA/AGA status – for index and comparison children 194
5.7.1.2 Performance on the Quick Neurological Screening Test by SGA/AGA status – index children and comparison children

Section 8 Comparison of Neuromotor Functioning by Gender 198
5.8.1 Motor competence 198

Chapter 5 cont.

5.8.1.1 Performance on the Movement Assessment Battery for Children by gender – for index and comparison children 198
5.8.1.2 Performance on the Quick Neurological Screening Test by gender – index children and comparison children 200

Section 9 Comparison of Neuromotor Functioning by Birthweight Groupings 202
5.9.1 Motor competence 202
5.9.1.1 Performance on the Movement Assessment Battery for Children by birthweight grouping – for index and comparison children 202
5.9.1.2 Neurological functioning – index children versus comparison children by birthweight groupings 204

Section 10 Investigation of Gradient Effect by Birthweight Groupings: <1000g, 1000-1499g and ≥1500g 206
5.10.1 Comparison of score of cognitive ability and education attainment by birthweight groupings 206
5.10.1.1 Distribution of IQ by birthweight groupings: <1000g, 1000g-1499g and ≥1500g 206
5.10.1.2 Comparison of composite general, verbal and visual IQ scores by birthweight groupings: <1000g, 1000-1499g and ≥1500g 207
5.10.1.3 Comparison of scores of scholastic attainment by birthweight groupings: 1000g, 1000-1499g and ≥1500g 209
5.10.2 Neuromotor competence – by birthweight grouping 210
5.10.2.1 Comparison of performance on Movement Assessment Battery for Children – by birthweight groupings; <1000g, 1000g-1499g and ≥1500g 210
5.10.2.2 Comparison of performance on Quick Neurological Screening Test – by birthweight groupings: <1000g, 1000g-1499g and ≥1500g 211

Section 11 An Investigation of the Importance of Employing Control Groups and Avoiding the use of Outdated Published Test Norms 213
5.11.2 The use of concurrent norms in relation to the distribution of IQ by birthweight groupings 214
5.11.3 The use of concurrent norms in relation to the proportion of index children functioning below the 10th percentile in reading and number

Chapter 5 cont.

Section 12 Investigation of the Relationship between Motor Competence and Cognitive Ability and Motor Competence and School Attainment 217

5.12.1 Association between motor competence and performance on the visual processing and verbal processing scales of the BAS 217

5.12.2 Does poor motor functioning ever occur in isolation? 222

5.12.3 Movement ABC and Quick Neurological Screening Test in relation to measures of scholastic attainment 222

Section 13 Performance of index children in special schools 227

Volume 2

Chapter 6 The Scottish Low Birthweight Study (Eight Year Follow Up) – Discussion 228

6.1 General summary 229

6.2 Interobserver variation 229

6.3 Index children in special education 229

6.3.1 Methodological considerations 229

6.3.2 Performance of index children in special schools 230

6.3.3 The identification of appropriate matched controls for index children in special education 230

6.4 Cognitive abilities 231

6.4.1 Importance of employing control groups and avoiding the use of outdated published test norms 231

6.4.2 The use of concurrent norms in relation to the distribution of IQ by birthweight groupings 232

6.4.3 The use of concurrent norms in relation to the proportion of index children functioning below 10th percentile on measures of scholastic attainment 233

6.5 Consistency in the findings from this study and other large scales controlled studies of VLBW or very premature children 235

6.5.1 Shortcomings in the coverage of the literature in the reports of a small number of other study groups 235

Chapter 6 cont.

6.6 Cognitive abilities – performance on BAS subscales 236
6.6.1 Is VLBW associated with dyslexia/specific learning difficulties 237
6.6.2 The provision of additional resources for children with particular educational needs 238
6.6.2.1 Importance of achieving 100% follow up or documenting the dropouts 239
6.6.3 The association between short term auditory memory and reading ability 240

6.7 To what extent are the British Ability Scales valid measures of discrete areas of cognitive functioning? 242

6.8 Performance in basic literacy and numeracy skills 244
6.8.1 Underachievement in basic literacy and numeracy skills 245
6.8.2 Reading and number difficulties and the provision of learning support 246

6.9 Neuromotor functioning 248
6.9.1 Movement Assessment Battery for Children (Movement ABC) 248
6.9.2 Quick Neurological Screening Test (QNST) 248
6.9.3 Screening tools for use in education 249
6.9.4 Do incontrovertible neuromotor difficulties ever occur in isolation? 251

6.10 Children who were small for gestational age 251
6.10.1.1 Investigation into differences in cognitive ability and scholastic attainment in the index group according to SGA/AGA status 253
6.10.1.2 Investigation into differences in cognitive ability and scholastic attainment in the comparison group according to SGA/AGA status 254
6.10.2 SGA/AGA differences in neuromotor functioning 256
6.10.2.1 Investigation into differences in motor competence and neurological functioning in the index group according to SGA/AGA status 256
6.10.2.2 Investigation into differences in motor competence and neurological functioning in the comparison group according to SGA/AGA status 257
6.10.3 How are differences in outcome of SGA children born at early and later gestation to be explained? 258

Chapter 6 cont.

6.11 Gender Differences 259
6.11.1 Gender differences in measures of cognitive ability 259
6.11.1.1 Gender differences in measures of cognitive subskills 260
6.11.1.1.1 Comparison of findings on gender differences in cognitive ability between this and other studies 260
6.11.1.2 Gender differences in measures of scholastic attainment 261
6.11.2 Gender differences in measures of neuromotor competence 264
6.11.2.1 Motor competence 264
6.11.2.2 Neurological functioning 264

6.12 Evidence of a gradient of risk with decreasing birthweight 265
6.12.1 Comparison of scores of cognitive ability by birthweight groupings 266
6.12.2 Comparison of scores of scholastic attainment by birthweight groupings 266
6.12.3 Comparison of scores of motor competence and neurological functioning by birthweight groupings 267

6.13 Is statistical significance in differences between index and comparison children necessarily clinically relevant? 268

6.14 Recent developments in neonatology and the implications for longitudinal research of very low birthweight and very premature infants 270

6.15 Strengths and limitations of the Scottish Low Birthweight Study 272
6.15.1 Key strengths of the study 272
6.15.1.1 Follow up rate 272
6.15.1.2 Nature of the cohort 273
6.15.1.3 The matching process 273
6.15.1.4 Assessors were blind to the case status of the children 273
6.15.2 Key limitations of the study 274
6.15.2.1 Lack of comparison group in previous phases of the study 274
6.15.2.1.1 Problems of consistency in diagnosis 274
6.15.2.2 Change in the criteria for cohort membership 275
6.15.2.3 Potentially important areas of development not investigated 276

Chapter 6 cont.

6.16 Changes in the level of cognitive functioning over time 277
6.16.1 Is the recent literature suggestive of a deterioration in cognitive functioning with maturation for VLBW/very premature children? 278

6.17 Predictors of later outcome in VLBW children 279
6.17.1 The association of socioeconomic variables with outcome 281

6.18 Psychological theories and low birthweight research 283
6.18.1 Does sensorimotor thinking only influence conceptual development in early childhood? 285
6.18.2 Do theories of child development pertain to the population of VLBW children? 285
6.18.2.1 Fetal brain development at different stages of gestation 286
6.18.2.2 Is the process of myelination in VLBW children disrupted? 287
6.18.2.3 Do theories of child development pertain to the population of VLBW children? – conclusion 288

6.19 Conclusion 288

Epilogue 290

References 291

Appendices

Appendix 1 Additional descriptive statistics – a detailed description of the birthweight and gender characteristics of the index and comparison groups 363
Appendix 2 Additional details of statistical analyses – differences in mean composite IQ and sub skills scores (British Ability Scales) between the index (all <1500g) and comparison groups 380

Appendix 3 Investigation of SGA/AGA differences – detailed description of two-way ANOVAs for cognitive sub skills by SGA/AGA status and case 388
Appendix 4 Detailed description of individual items of the Quick Neurological Screening Test by SGA/AGA status – index children and comparison children 402

Appendix 5 Investigation of gender differences – a detailed description of two-way ANOVAs for cognitive sub skills by gender and case 407

Appendices cont.

Appendix 6 Investigation of differences in neurological outcome for index and comparison children by birthweight groupings – a detailed description of the individual items of the Quick Neurological Screening Test by birthweight groupings 419

Appendix 7 Investigation of gender differences in neurological outcome for index and comparison children – a detailed description of the individual items of the Quick Neurological Screening Test by gender 424

Appendix 8 Investigation of relationship of motor competence to intellectual functioning – a detailed description of two-way ANOVAs for verbal and non verbal scales of BAS by motor competence and level of intellectual functioning (index group) 430

Appendix 9 The use of concurrent norms in relation to the proportion of index children functioning below the 10th percentile in reading and number 453

Appendix 10 Relationship between performance on Recall of Digits (BAS), General IQ and Word Reading Scores (poor performance for both Recall of Digits and General IQ is defined as > 1SD below the mean) 455

Content of Tables

Chapter 1

Table 1.2 Neonatal mortality rates reported in hospital studies from the first half of the twentieth century: by birthweight groupings 2

Table 1.8 A meta analysis of three population-based studies in England, Scotland and the Netherlands from the 1980s; by gestational age 18

Chapter 2

Table 3.3.3 Principal difficulties in conducting follow-up studies of VLBW infants (based on Aylward et al., 1989)

Chapter 4

Table 4.1.3 The number of birth, deaths and survival rates per 1000 live births of infants with birthweights<1750 g, in Scotland in 1984: death and survival rates by birthweight group 121

Table 4.1.5 Summary of two-year outcomes based on medical assessments: numbers (%) of children with impairments by birthweight group 122

Table 4.1.6.1 The number of deaths and survival rates per 1000 live births at 4.5 years of age of the Scottish Low Birthweight Cohort (<1750 g): death and survival rates by birthweight group 124

Table 4.1.6.2 Summary of disability ratings at 4.5 years of age: numbers (%) of children by birthweight group 124

Table 4.1.6.3 Characteristics of the Scottish Low Birthweight cohort (<1750 g) at 4.5 years of age by birthweight group 125

Table 4.1.7 The number of deaths, survival rates per 1000 live births and success of follow-up at 8.9 years of age of the Scottish Low Birthweight Cohort (<1500 g): death and survival rates by birthweight group 126

Chapter 5

Table 5.1.1.1	Mean birthweights of index children	146
Table 5.1.1.2	Difference in mean birthweights of female and male index children	147
Table 5.1.1.3.1	Mean birthweights of index children (<1000g)	148
Table 5.1.1.3.2	Difference in mean birthweights of female and male index children <1000g	148
Table 5.1.1.3.3	Mean birthweights of index children (1000-1499g)	149
Table 5.1.1.3.4	Difference in mean birthweights of female and male index children 1000-1499g	150
Table 5.1.2.1	Mean gestational age of index children (all <1500g)	150
Table 5.1.2.1	Mean gestational age of index children (all <1500g)	151
Table 5.1.2.2.1	Mean gestational age of index children (<1000g)	152
Table 5.1.2.2.2	Difference in mean gestational ages of female and male index children (<1000g)	153
Table 5.1.2.2.3	Mean gestational age of index children (1000-1499g)	154
Table 5.1.2.2.4	Difference in mean gestational ages of female and male index children (1000-1499g)	155
Table 5.1.3.1	Mean age at time of assessment of index children	156
Table 5.1.3.2	Mean age at time of assessment of comparison children	158
Table 5.1.4	SGA status of index children (excluding those in special education) and comparison children	158
Table 5.1.5	Socio demographic characteristics of the index and comparison groups	159
Table 5.2.1.1	Distribution of IQ – index children (<1500g) and comparison children (using comparison group norms)	161
Table 5.2.1.2	Difference in mean IQs - index (<1500g) versus comparison children	161
Table 5.2.2	Mean T scores for cognitive sub-skills (British Ability Scales) - index children and comparison children	163
Table 5.2.3	Mean general, verbal and visual IQs(British Ability Scales) - index children and comparison children	164
Table 5.2.4	Mean scores and numbers of children functioning below 10th percentile (for the comparison group) on school attainment tasks(British Ability Scales) - index children and comparison children	165

Chapter 5 cont.

Table 5.2.5.1.1.1 Differences between index and comparison females and males on basic number skills without controlling for general IQ 166

Table 5.2.5.1.1.2 Differences between index and comparison females and males on basic number skills controlling for general IQ (ANCOVA) 167

Table 5.2.5.1.2.1 Differences between index and comparison females and males on reading skills without controlling for general IQ 167

Table 5.2.5.1.2.2 Differences between index and comparison females and males on reading skills controlling for general IQ (ANCOVA) 167

Table 5.3.1.1 Distribution of IQ by SGA-AGA status – index children and comparison children (using comparison group norms) 168

Table 5.3.1.2 Differences in mean General IQ scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test 169

Table 5.3.2 Mean cognitive sub skills score (SD) (British Ability Scales) by SGA/AGA status – index and comparison children 170

Table 5.3.3 Mean general, verbal and visual IQs(British Ability Scales) by SGA/AGA status – index and comparison children 172

Table 5.3.4 Mean scores and numbers of children functioning below 10th percentile on school attainment tasks (British Ability Scales) - index children and comparison children by SGA/AGA status 173

Table 5.4.1.1 Distribution of IQ by gender – index children and comparison children (using comparison group norms) 175

Table 5.4.1.2 Differences in mean General IQs by gender and case status: two – way ANOVA and Tukey HSD post hoc test 176

Table 5.4.2 Mean cognitive sub skills score (SD) (British Ability Scales) by gender and case status 177

Table 5.4.3 Mean general, verbal and visual IQs(British Ability Scales) by gender and case status 178

Table 5.4.4.1 Mean scores and numbers of children functioning below 10th percentile on school attainment tasks(British Ability Scales) - index children and comparison children by gender 178

Chapter 5 cont.

Table 5.5.1 Socio demographic characteristics of the index and comparison groups by birthweight groupings 180

Table 5.5.2.1 Distribution of IQ by birthweight groupings – index children and comparison children (using comparison group norms) 181

Table 5.5.2.2 Difference in mean IQ scores - index (<1000g) versus comparison children 182

Table 5.5.2.3 Difference in mean IQs - index (1000-1499g) versus comparison children 183

Table 5.5.2.4 Mean T scores for cognitive sub-skills and scholastic attainment(British Ability Scales) by birthweight grouping - index children and comparison children 184

Table 5.5.2.5 Mean general, verbal and visual IQs(British Ability Scales) by birthweight grouping - index children and comparison children 185

Table 5.5.2.6 Mean scores and numbers of children functioning below 10th percentile (for respective comparison groups) on school attainment tasks(British Ability Scales) by birthweight grouping - index children and comparison children 185

Table 5.5.3.1.1 Differences between index and comparison females and males on basic number skills without controlling for general IQ – by birthweight groupings 187

Table 5.5.3.1.2 Differences between index and comparison females and males on basic number skills controlling for general IQ (ANCOVA) – by birthweight groupings 187

Table 5.5.3.2.1 Differences between index and comparison females and males on word reading skills without controlling for general IQ – by birthweight groupings 188

Table 5.5.3.2.2 Differences between index and comparison females and males on word reading skills controlling for general IQ (ANCOVA) – by birthweight groupings 188

Table 5.6.1.1.1 Numbers (%) of children falling below the 10th percentile (for the control children) on the Movement Assessment Battery for Children: VLBW and comparison groups 189

Table 5.6.1.1.2 Numbers (%) of children falling <10th centile for competence at eight years of age VLBW and comparison groups 190

Table 5.6.1.2.1 Overall performance on the Quick Neurological Screening Test: VLBW and comparison groups 191

Chapter 5 cont.

Table 5.6.1.2.2 Performance on individual items of the Quick Neurological Screening Test: VLBW and comparison groups 193

Table 5.7.1.1 Numbers (%) of children falling <10th centile for motor skills at eight years of age by SGA/AGA status: VLBW and comparison groups by birthweight groupings 195

Table 5.7.1.2 Overall performance on the Quick Neurological Screening Test at eight years of age by SGA/AGA status: VLBW and comparison children 197

Table 5.8.1.1 Numbers (%) of children falling <10th centile for motor skills at eight years of age by gender: VLBW and comparison groups by birthweight groupings 199

Table 5.8.1.2 Overall performance on the Quick Neurological Screening Test at eight years of age by genders: VLBW and comparison children 201

Table 5.9.1.1 Numbers (%) of children falling <10th centile for motor skills at eight years of age: VLBW and comparison groups by birthweight groupings 203

Table 5.9.1.2 Overall performance on the Quick Neurological Screening Test: VLBW and comparison groups by birthweight groupings 205

Table 5.10.1.1 Distribution of IQ by birthweight groupings: <1000g, 1000-1499g and ≥1500g (using comparison group norms) 206

Table 5.10.1.1.2 Investigation of a gradient effect by birthweight in differences between mean IQ scores (ANOVA) and Tukey HSD test 207

Table 5.10.1.2.1 Mean general, verbal and visual IQs(British Ability Scales) by birthweight grouping: <1000g, 1000-1499g and ≥1500g 207

Table 5.10.1.2.2 Investigation of a gradient effect by birthweight in differences between Mean verbal IQ scores (ANOVA) and Tukey HSD test 208

Table 5.10.1.2.3 Investigation of a gradient effect by birthweight in differences between mean visual IQ scores (ANOVA) and Tukey HSD test 208

Chapter 5 cont.

Table 5.10.1.3.1 Mean scores and numbers of children functioning below 10th percentile (for the comparison group) on school attainment tasks (British Ability Scales) by birthweight grouping: <1000g, 1000-1499g and ≥1500g 209

Table 5.10.1.3.2 Investigation of a gradient effect by birthweight in differences between reading scores (ANOVA) and Tukey HSD test 209

Table 5.10.1.3.3 Investigation of a gradient effect by birthweight in differences between mean number skills scores (ANOVA) and Tukey HSD test 210

Table 5.10.2.1 Numbers (%) of children falling <10th centile for motor skills at eight years of age - by birthweight groupings: <1000g, 1000-1499g and ≥1500g 210

Table 5.10.2.2 Overall performance on the Quick Neurological Screening Test - by birthweight groupings: <1000g, 1000-1499g and ≥1500g 211

Table 5.11.1.1 Distribution of IQ – index children (<1500g) versus comparison children (using test norms) 213

Table 5.11.1.2 Distribution of IQ – index children (<1500g) and comparison children (using comparison group norms) 214

Table 5.11.2.1 Distribution of IQ by birthweight groupings – index children and comparison children (using test norms) 215

Table 5.11.2.2 Distribution of IQ by birthweight groupings – index children and comparison children (using comparison group norms) 215

Table 5.12.1.1 Differences in mean Word Definitions scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test 218

Table 5.12.1.2 Differences in mean Recall of Designs scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test 220

Table 5.12.3.1 Association between performance on the Quick Neurological Screening Test, Movement ABC and school attainment – index children 223

Table 5.12.3.2 Association between performance on the Quick Neurological Screening Test, Movement ABC and Number Skills (ANOVA) and Tukey HSD test – index children 223

Table 5.12.3.3 Association between performance on the Quick Neurological Screening Test, Movement ABC and Word Reading (ANOVA) and Tukey HSD test – index children 223

Table 5.12.3.4 Association between performance on the Quick Neurological Screening Test, Movement ABC and school attainment – index and comparison children together 224

Chapter 5 cont.

Table 5.12.3.5 Association between performance on the Quick Neurological Screening Test, Movement ABC and Number Skills (ANOVA) and Tukey HSD test – index and comparison children together 225

Table 5.12.3.6 Association between performance on the Quick Neurological Screening Test, Movement ABC and Word Reading (ANOVA) and Tukey HSD test – index and comparison children together 225

Content of Figures

Chapter 1

Figure 1.9.2 Infant receiving extra-corporeal membrane oxygenation 21
Figure 1.9.3 Infant receiving inhaled nitric oxide 22

Chapter 4

Figure 4.2.6.1.1 Throwing the beanbag (Movement ABC) 133
Figure 4.2.6.1.2 Flower trail (Movement ABC) 134
Figure 4.2.6.1.3 One board balance (Movement ABC) 135
Figure 4.2.6.2.1 Matrices (British Ability Scales) 136
Figure 4.2.6.2.2 Block Design (British Ability Scales) 137
Figure 4.2.6.2.3 Basic Number Skills (British Ability Scales) 137
Figure 4.2.6.2.4 Word Reading (British Ability Scales) 138

Chapter 5

Figure 5.1.1.1 Birthweight distribution for index children (all<1500g) 145
Figure 5.1.1.2 Box and whisker plot of birthweight by gender for index children (all <1500g) 146
Figure 5.1.1.3.1 Birthweight distribution for index children (all<1000g) 147
Figure 5.1.1.3.2 Box and whisker plot of birthweight by gender for index children <1000g 148
Figure 5.1.1.3.3 Birthweight distribution for index children (all 1000-1499g) 149
Figure 5.1.1.3.4 Box and whisker plot of birthweight by gender for index children 1000-1499g 150
Figure 5.1.2.1.1 Gestational age (weeks) distribution for index children (all<1500g) 151
Figure 5.1.2.1.2 Box and whisker plot of gestational age by gender for index children (all <1500g) 152
Figure 5.1.2.2.1 Gestational age (weeks) distribution for index children (all<1000g) 153
Figure 5.1.2.2.2 Box and whisker plot of gestational age by gender for index children (<1000g) 154
Figure 5.1.2.2.3 Gestational age (weeks) distribution for index children (all 1000-1499g) 155
Figure 5.1.2.2.4 Box and whisker plot of gestational age by gender for index children (1000-1499g) 156

Chapter 5 cont.

Figure 5.1.3.1 Age distribution for index children at time of assessment (all<1500g) 157

Figure 5.1.3.2 Age distribution for comparison children at time of assessment 158

Figure 5.2.1 Box and whisker plot for general IQ by case status 162

Figure 5.2.5.1 Relationship between general IQ and measures of scholastic attainment – index children (Pearson Product Moment Correlation) 165

Figure 5.2.5.2 Relationship between general IQ and measures of scholastic attainment – comparison children (Pearson Product Moment Correlation) 166

Figure 5.3.1 Categorised box and whisker plot for general IQ by SGA/AGA and case status 170

Figure 5.4.1 Categorised box and whisker plot for general IQ by gender and case status 176

Figure 5.5.2.1 Box and whisker plot for general IQ by case status (<1000g and controls) 182

Figure 5.5.2.2 Box and whisker plot for general IQ by case status (1000 - 1499g and controls) 183

Figure 5.12.1.1 Plot of means (two way interaction) for Word Definitions by motor competence and IQ status (index group) 219

Figure 5.12.1.2 Plot of means (two way interaction) for Recall of Designs by motor competence and IQ status (index group) 220

Figure 5.12.3.1 Categorised box and whisker plot for Word Reading scale by QNST and Movement ABC (all children index and comparison) 225

Figure 5.12.3.2 Categorised box and whisker plot for Basic Number Skills scale by QNST and Movement ABC (all children index and comparison) 224

Abstract

The prevalence of learning problems and impairments in cognitive ability and neuromotor functioning in a total geographically based very low birthweight population (N=324) was compared at eight years of age with that in a population comprising two classroom peers, matched for gender and age (N=590). The sociodemographic characteristics of the index and comparison groups were similar. The analyses reported in this thesis do not include those children being educated in the special school sector – as appropriate controls could not be identified.

The mean IQ score for the index group was significantly lower than the mean IQ score for the comparison group. A significantly greater proportion of the index group had serious cognitive impairment, that is, they were performing more than 2 SD below the mean. The index children were found to be significantly underperforming in relation to the comparison children on tests of reading and number – although after controlling for IQ (ANCOVA) the difference between the two groups was no longer significant for reading.

In terms of neuromotor competence, a significantly greater proportion of the index group than the comparison group were functioning below the 10th percentile. The 10th percentile (for the comparison group) was taken as the cut off to define motor impairment and 36% of the index group were categorised as motor impaired. Furthermore, a significantly greater proportion of the index group were classified as "suspicious" or "abnormal" in terms of their neurological status.

The performance of the index children was also analysed by birthweight groupings (below 1000g and 1000 to 1499g) because of increasing clinical interest in the outcomes of children born on the limits of viability. The mean IQ scores for both index groups were significantly lower than those of their respective comparison groups. In all cognitive subscales apart from that testing short term auditory sequential memory, both index groups performed less well. Both index groups performed less well in tests of reading and number – although the differences were no longer significant after controlling for IQ. Fifteen per cent of the below 1000g index children and six per cent of those with birthweights 1000 to1499g attended special

schools. Index children in both groupings who attended mainstream schools performed significantly less well in tests of neuromotor function than their peers.

The differential effects of being small for gestational age (SGA) and of appropriate size for gestational age (AGA) on outcome measures of cognitive ability, scholastic attainment and neuromotor functioning were investigated. No differences were found between SGA and AGA index children, probably because the mean gestational age of the AGA children was lower than that of the SGA children. The SGA comparison children performed significantly less well on some measures of cognitive ability than the AGA comparison children.

Gender differences on measures of cognitive ability, scholastic attainment and neuromotor functioning were investigated for both index and comparison groups. No gender differences were found in the index group with the exception of the ball skills element of the motor skills assessment where the performance of the females was poorer. The picture was the same for the comparison group except that, additionally, females were outperforming boys on tests of scholastic attainment.

The extent to which under reporting of serious cognitive impairment can result from the use of published test norms was investigated. A larger proportion of index children were classified as seriously impaired in terms of cognitive ability when their performance was measured against norms derived from the comparison group. The same was true also for performance on measures of scholastic attainment.

The possibility that motor impairment might affect performance on the visual items of the cognitive assessment battery used in this study was explored. While there was some evidence of such an effect particularly for the index children of satisfactory overall cognitive ability, the results of this investigation were inconclusive.

The relationship between motor competence, neurological functioning and performance on measures of scholastic attainment was investigated. This strand of the investigation demonstrated that the test of neurological functioning used in this study is a useful screening tool for identifying children at high risk of learning difficulties.

Chapter One

Low Birthweight Research - An Introduction

1.1 A brief history

Since time immemorial it has been recognised that infants who are very tiny at birth or those who are born long before they are expected have a much poorer chance of survival.

Such children were said to suffer from *debilitas vitæ*. In most societies of the world such infants were allowed to die as this "weakness of life" carried with it the unwelcome prospect of a need for lifelong care; a burden regarded as too great for family or society.

The abandonment of tiny, feeble newborn infants, based on physical examination, was an accepted practice in different areas of the world in ancient times. In Sparta, for example, every newborn infant was examined by an appointed committee and only the strong and healthy were allowed to survive. Also, in Rome during the second century, a Greek physician, Soranus of Epphesus, was responsible for drawing up a description of “an infant worth rearing”. The tiny, weak premature infant, needless to say, did not feature in his characterisation (Desmond, 1991).

Only those babies who had the constitution to adapt to life with little in the way of support survived; certainly there was no question of special care. Not unnaturally, some mothers wished to save their tiny offspring and they used traditional knowledge to nurture and sustain them – keeping their infants warm and feeding them regularly.

1.2 Early epidemiological research

By the beginning of the twentieth century, society, at least in the Western world, started to care for these infants who were born on the limits of viability. The responsibility for evaluating how well these infants fared fell to the medical profession. The main measure of outcome was neonatal death, as few of these infants survived.

The few published studies from the first half of the 20th century report very high mortality rates during hospital stay (Table 1.2).

Table 1.2
Neonatal mortality rates reported in hospital studies from the first half of the twentieth century: by birthweight groupings

	Birthweight Groupings		
	<1000g	1000g - 1499g	all infants <2500g
Neonatal mortality during hospital stay (%)	84% (Ylppö, 1919) to 100% (Blegen, 1928)	80% (Ylppö, 1919) to 49% (Tyson, 1946)	91% Looft (1928) to 17% (Blegen, 1953)

The ranges in rates of neonatal mortality are remarkably wide – especially for the heavier birthweight grouping. This is likely to be due in part to differences in methods of recording and reporting mortality data. It has been reported recently that errors in registered birth weight occur even in the present day and that such errors can cause bias in the reporting of mortality statistics (Anand & Pharoah, 2000). The authors suggest that the bias arising from these errors should be taken into consideration when mortality rates and their trends are being interpreted. It is likely that if errors of this sort still occur there is a good chance that they did so in the first half of the 20th century.

As will be discussed below these early studies were methodologically flawed in a number of ways. It is also the case that these studies cover almost half a century and although they all precede the advent of neonatal intensive care it is possible that neonatal care practices did change throughout these decades with associated changes in mortality rates.

1.3 Definitions of prematurity in Biblical times

In Biblical times a full term pregnancy was generally regarded as being 10 lunar months. This was not universally accepted with some hypothesising that full gestation was as short as nine months and others that it was as long as 11 months. It has been suggested that the dearth of accurate information about the course of gestation was not detrimental as far as Moses was concerned – who is believed to have been born prematurely. It seems that his early arrival may have prevented him from dying at the hands of the Egyptian soldiers who were under orders to drown, or otherwise kill, male children (Dumont, 1990). The case of Moses is one of the very few where premature birth increased the chance of survival.

1.3.1 Attempts to define prematurity in the late 19th and early 20th centuries

A definition of prematurity, based on birthweight, was postulated in 1886 (Schulte, Michaelis & Nolte, 1967). Subsequently, the definition of prematurity as any infant born with a birthweight less than 2500g was adopted by the World Health Organisation. Notwithstanding the fact that this definition was called into question, for example, by von Pfaundler in 1946, it was not until the mid-1960s that it was widely acknowledged that roughly one third of infants born at less than 2500g are, in fact, full term at birth (Bonham, 1965). Only then was the definition of prematurity based on birthweight abandoned and redefined in term of postnatal gestational age assessment (Usher, McLean & Scott, 1966).

1.3.2. Current definitions of low birthweight, very low birthweight and extremely low birthweight and of prematurity

According to the World Health Organisation's definitions, an infant with a birthweight of less than 2500g is termed as being of low birthweight (LBW); if the birthweight is less than 1500g, it is described as being of very low birthweight (VLBW) and if the infant's birthweight is less than 1000g, it is described as being of extremely low birthweight (ELBW) (Expert Committee on Maternal and Child Health, WHO, 1961).

The World Health Organisation's definition for premature birth is where the birth takes place before 37 completed weeks of gestation (WHO, 1977).

(The issue of definitions of low birthweight and prematurity is revisited in Chapter 3 in relation to methodological issues.)

1.3.3 Difficulties in accurately assessing gestational age

In the 21st century, appointed committees are no longer set up to undertake the assessment of newborn infants to determine whether or not they should be allowed to survive. Gestational age is, however, sometimes used to guide decisions concerning whether or not to treat aggressively infants born on the limits of viability. Yet there is still no absolutely infallible method of assessing gestational age postnatally. This is particularly true for infants born at less than 28 weeks gestation (Donovan, Tyson, Ehrenkranz, Verter, Wright, Korones, Bauer, Shankaran, Stoll, Fanaroff, Oh, Lemons, Stevenson & Papile, 1999). Early ultrasound examination has, however, greatly improved estimates of gestation age antenatally. While this technique has become widespread throughout the 1990s it is still not universally administered. Where ultrasound examination is not employed estimates of gestational age are based either on the mother's report of the date of her last menstrual period or on some form of postnatal assessment.

1.3.3.1 Birthweight versus gestational age as the basis for cohort membership in follow up studies

Prior to the 1990s studies investigating mortality and morbidity in tiny, immature infants tended to be based on birthweight rather than gestational age (Hack and Fanaroff, 1988). The present study represents an eight year follow up of the Scottish Low Birthweight Study – which was established in 1984. By definition the Scottish Low Birthweight Study is based on a birthweight cut off. As with many other studies from this era birthweight rather than gestational age was taken as the criterion for cohort membership as a result of concerns about the accuracy of estimates of gestational age of the infants. In the mid 1980s early ultrasound confirmation was less common than is the case now and the reliability of postnatal assessment of gestational age was poor (Sola & Chow, 1999).

Clearly both birthweight and gestational age are measures of the adequacy of fetal development and the two are highly correlated (McCormick, 1988). The combinations of these two measures have also increased in importance, giving rise to distinctions such as small versus appropriate for gestational age.

Throughout the 1990s, information on the perinatal and longer term outcomes of these vulnerable infants based on gestational age rather than on birthweight has become more important. This is because, as survival rates have increased, decisions have had to be taken regarding the timing and method of delivery of infants when faced with extreme immaturity or maternal complications such as pre eclampsia. This information is also invaluable when decisions have to be taken regarding whether or not to actively resuscitate an extremely immature infant.

It should be recognised that the cut off for VLBW (less than 1500g) is no more than an arbitrary point on a continuous distribution of birthweights – it has no particular significance. Indeed, birthweight distributions differ across different groups, raising questions about the applicability of a single birthweight cut off for all births. Nevertheless, VLBW (and more recently ELBW) has retained its usefulness as a measure of neonatal risk – it serves to distinguish a group of infants at increased risk for mortality and a range of other problems. The continued use of a single standard is also helpful in terms of making comparisons between groups and over time.

1.4 Epidemiology of low birthweight

The aim of this section is to provide the reader with a comprehensive overview of the epidemiology of low birthweight. Many studies are cited below but it is not the intention to rigorously critically evaluate this body of research – although some comment on methodology and data sources will be made. The substantial review of the literature on low birthweight research follows in Chapter 2 and there will be a greater degree of critical evaluation at this stage.

1.4.1 Social class

A common problem in medicine, and one that has particularly affected the research in the area of low birthweight and preterm birth, is the misinterpretation of observed associations as representing a causative relationship. There are many factors that confound these associations but socioeconomic status is probably the most important one (e.g. Ancel, Saurel-Cubizolles, Di Renzo, Papiernik & Breart, 1999; Dammann, Walther, Allers, Schroder, Drescher, Lutz, Veelken & Schulte, 1996; Eilers, Desai, Wilson & Cunningham, 1986).

A recent study from France which involved the cooperation of study groups from 15 European countries has reported on the risk factors for premature birth (Ancel et al., 1999). The study included 1675 very preterm infants, 3652 moderately preterm infants and an unmatched control group of 7965 full term infants born between 1994 and 1997. The authors reported that low socioeconomic status, older maternal age and adverse previous pregnancy outcomes were significantly related to very preterm birth and to moderately preterm birth. They added that these factors were more strongly associated with very preterm birth than with moderately preterm birth, for both spontaneous and induced deliveries.

Other factors that were reported to be associated with very and moderately preterm birth were smoking during pregnancy and young maternal age. There was no difference in the strength of the associations for very and moderately preterm birth for these factors. The authors concluded that their results suggested that risk factors for very and moderately preterm births are similar but that the strength of the associations differ, especially for social factors and obstetric history. (Maternal age and smoking as risk factors for low birthweight and premature birth are discussed in more detail below.)

A regional study that set out to investigate perinatal, sociodemographic and neuromotor determinants of cognitive development of very low birthweight-children (VLBW) at six years of age was undertaken in Hamburg, Germany (Dammann, Walther, Allers, Schroder, Drescher, Lutz, Commentz, Veelken & Schulte, 1995). The study children were 298 survivors of a regional three year birth cohort born between 1983 and 1986. The children were administered standardised tests of cognitive ability, visuomotor integration, language and memory skills. The authors reported a major influence of sociodemographic status and a minor importance of perinatal variables for the cognitive development of VLBW children.

A further report was issued from the same study group (Damman et al., 1996). This provided additional detail on the same follow up of their VLBW cohort. The authors reported that visuomotor development was influenced by neurological status but not by socioeconomic status. Intelligence and language skills, on the other hand, were much more closely related to socioeconomic background than to neurological morbidity.

A review from the early 1990s considered nine studies of ELBW infants and 16 studies of VLBW infants from the previous decade (Ornstein, Ohlsson, Edmonds & Asztalos, 1991). The authors reported that low socioeconomic status was the most frequently reported predictor of poor outcome.

1.4.2 Ethnic origin

Although survival rates have improved over the last two or three decades for very low birthweight infants born to both black and white mothers, the racial disparity in survival rates has increased (e.g. Pallotto, Collins & David, 2000; Alexander, Tompkins, Allen & Hulsey, 1999). Alexander et al. investigated temporal changes in birthweight distributions according to race. Their study considered white and African-American infants born between 1975 and 1994. The authors reported that while the percentage of children born at very low birthweight increased, neonatal mortality rates declined markedly. They also reported, however, that the reduction in the rate of neonatal mortality was significantly greater for white infants than for African-American infants. The authors postulated that the decline in neonatal mortality of VLBW infants is probably related to high risk obstetric and neonatal care and that technological developments in these areas may have differentially benefited white infants.

A study using the US national linked live birth/infant death data set for 1988 found that VLBW infants accounted for 1.2% of all births but 64.2 % of all deaths (Wise, Wampler & Barfield, 1995). With regard to racial disparity, the authors reported that the rate of VLBW for white mothers was 0.93% as compared with 2.79% for black mothers. The authors also reported that racial disparity in neonatal mortality was greatest for infants born with birthweights less than 1000g.

A study of 10 to 14 year old mothers, using the US national linked live birth/infant death data set for 1983-1986 found that young black mothers were more at risk of delivering infants who were very low birthweight, small for gestational age, and very preterm (Leland, Petersen, Braddock & Alexander, 1995). The authors also reported, however, that neonatal mortality rates were higher for VLBW and LBW white infants, that the neonatal mortality rates were similar for normal birthweight infants of both races, but the neonatal mortality rates were 3.7 to 7.4 times higher among black infants with birth weights more than 4,250 grams. The authors concluded that poor pregnancy outcome is common among young adolescents and that young black adolescents appear to be particularly vulnerable. (The association between maternal age and pregnancy outcome is described in greater detail below.)

1.4.3 Maternal factors

1.4.3.1 Maternal illnesses

1.4.3.1.1 Pregnancy induced hypertension

Pregnancy induced hypertension can be classified as gestational hypertension, preeclampsia or severe preeclampsia (e.g. Xiong, Mayes, Demianczuk, Olson, Davidge, Newburn-Cook & Saunders, 1999). Using data from a population-based perinatal database in Suzhou, China Xiong et al. investigated the effect of these different types of pregnancy-induced hypertension on gestational age, preterm birth, birthweight, low birthweight, and intrauterine growth retardation. The authors reported that while gestation was 0.6 of a week shorter in women with severe preeclampsia than in women who were not experiencing pregnancy induced hypertension, the risk of preterm birth was not increased in any of their classifications of pregnancy-induced hypertension.

Xiong et al. reported that preeclampsia and severe preeclampsia increased the risk of intrauterine growth retardation and low birthweight whereas gestational hypertension was not associated with low birthweight.

A retrospective hospital based study in Ireland has reported upon risk factors associated with low birthweight in liveborn and stillborn infants (Geary, Rafferty & Murphy, 1997). Preeclampsia was reported to be one of the main risk factors for low birthweight in both the liveborn and stillborn groups. The authors added that while knowledge of abnormal growth antenatally significantly increases obstetric intervention, it continues to be difficult to detect poor growth antenatally.

1.4.3.1.2 Sexually transmitted diseases

There are few prospective studies of the association between sexually transmitted diseases and low birthweight and prematurity. There are, however, a small number of controlled studies that have reported an association between gonorrhoea and low birthweight (e.g. Elliot, Brunham, Laga, Piot, Ndinya-Achola, Maitha, Cheang & Plummer, 1990). A slightly more recent study of black pregnant women in Pretoria, South Africa – where the prevalence of genital infections is high – has reported an association between both gonorrhoea and syphilis and low birthweight and premature birth (Donders, Desmyter, De Wet & Van Assche, 1993).

1.4.3.2 Marital status

Unmarried mothers are at greater risk of delivering low birthweight infants with the low birthweight rate among infants being born to unmarried mothers being about twice that of infants born to married mothers (e.g. Sung, McGrady, Rowley, Hogue, Alema-Mensah & Lypson, 1993; Sung, Taylor, Blumenthal, Sikes, Davis Floyd, McGrady, Lofton & Wade, 1994). Sung et al., 1993, analysing population data for white and black mothers aged 10 to 49 years in Atlanta, Georgia, reported overall low birthweight rates of 132.8 vs. 63.9 per 1000 livebirths for unmarried and married mothers respectively.

Their investigation into the effect of maternal age and race on the association of marital status and birthweight demonstrated that while unmarried status increases the risk of low birthweight, this is more the case for older mothers than for teenage mothers.

Not unexpectedly, given the account above, race was also found to be a significant factor. When only normal birthweight infants were considered the rates of neonatal mortality per 1000 live births was highest for infants born to unmarried black teenagers (9.5), followed by that for infants born to married black teenagers (9.1), unmarried black adults (7.5), married black adults (4.8), married white teenagers (4.4), married white adults (3.4), unmarried white adults (2.4), and unmarried white teenagers (1.3) (Sung et al., 1994).

When only low birthweight infants were considered, however, the highest neonatal mortality rate per 1000 live births was found in infants born to married black adults (119), followed by unmarried black adults (103), married black teenagers (99.9), unmarried black teenagers (92.5), married white adults (92.1), married white teenagers (79.0), unmarried white adults (38.0), and unmarried white teenagers (26.3).

1.4.4 Smoking

Many controlled studies have reported that smoking during pregnancy is associated with a range of adverse outcomes. The first study to report upon the, now well established, association between maternal smoking and lowered birthweight was published in the 1950s (Simpson, 1957).

Many studies since the 1950s have reported not only the association between maternal smoking and lowered birthweight but also that the effect is dose dependent (e.g. Meyer, Jonas & Tonascia, 1976).

A more recent Swedish study has reported that older mothers who smoke are at greater risk of having small for gestational age infants while parous mothers who smoke are at particular risk of having low birthweight and premature infants (Cnattingius, Forman, Berendes & Graubard, 1993).

1.4.5 Drug and alcohol abuse

Maternal cocaine abuse during pregnancy has been associated not only with low birthweight, preterm birth and intrauterine growth retardation (e.g. Handler, Kistin, Davis & Ferre, 1991) but also with congenital malformations (e.g. Chavez, Mulinare & Cordero, 1989) and neurobehavioral complications (e.g. Dobereczak, Shanzer, Senie & Kandall, 1988).

It has been reported that cocaine use during pregnancy is associated with low birthweight, short gestation, short length and small head circumference after controlling for demographic and lifestyle factors (Bateman, Ng, Hansen & Heagarty, 1993). The authors also reported that birthweight deficits were even greater for infants whose mothers used cocaine in combination with other drugs and for infants born to mothers who specifically admitted to using crack.

The reader is referred to a review paper for a comprehensive account of the impact of prenatal exposure to both cocaine and marijuana on neonatal and long term outcomes (Richardson, Day & McGauhey, 1993).

Since the identification of fetal alcohol syndrome toward the end of the 1960s, a number of adverse effects on the fetus, including low birthweight, resulting from alcohol consumption during pregnancy have been reported (e.g. Borges, Lopez-Cervantes, Medina-Mora, Tapia-Conyer & Garrido, 1993) even when consumed in relative moderation (Verkerk, Van, Noord-Zaadstra, Florey, de Jonge & Verloove-Vanhorick, 1993).

It has also been suggested that binge drinking during critical stages in organ formation may constitute a particularly high risk for adverse outcomes in pregnancy and later childhood (Allebeck & Olsen, 1998).

1.4.6 Maternal age

It has been postulated that older primiparous women are at greater risk of having low birthweight or premature infants (e.g. Forman, Meirik & Berendes, 1984). This issue was explored in a study of 1382 white, primiparous mothers who delivered live singleton births (Barkan & Bracken, 1987). The authors reported that women delivering at 30 years of age or more were at no greater risk of having low birthweight or premature infants. While women over 35 were reported to have twice the rate of low birthweight and premature infants than women under 30, the difference was not statistically significant.

It has also been suggested that teenage pregnancy is associated with low birthweight and premature birth (e.g. Wessel, Cnattingius, Bergstrom, Dupret & Reitmaier, 1996; Fraser, Brockert & Ward, 1995). A prospective population based study from Sweden (Wessel et al., 1996) investigated the association of maternal characteristics and low birthweight or preterm birth. The authors reported that the overall prevalence of low birthweight in the region studied was 8% and the prevalence of preterm birth was 12%. The authors also found a significant association between low birthweight and low maternal age (less than or equal to 19 years).

A review article discussing the association between teenage pregnancy and low birthweight (Roth, Hendrickson, Schilling & Stowell, 1998) has suggested that young maternal age alone does not explain the higher rates of low birthweight infants born to adolescent females. The authors suggest that biological factors such as immaturity of the female reproductive system and inadequate prenatal weight gain must be considered together with sociocultural factors such as poverty and minority status. They argue that these biological and sociocultural factors combine to raise or lower the risk of delivering a low birthweight infant.

The importance of considering sociocultural factors in the association between teenage pregnancy and low birthweight has been taken up by an Israeli group (Seidman, Stevenson, Stevens-Simon, Ward & Fraser, 1996).

The authors take issue with studies that suggest that the higher risk for low birthweight and premature birth associated with young maternal age is a reflection of an underlying inherent biologic risk (e.g. Fraser et al., 1995). Seidman et al., argue first of all that nutritional factors have a significant influence on birth weight. They suggest that adolescent women tend not only to be underweight but are also very conscious of their body image and tend to gain less weight during pregnancy than older women. They suggest, furthermore, that some teenagers may actually try to avoid revealing their pregnancies by not putting on weight. However, this argument assumes that maternal weight and/or maternal weight gain is associated with infant birthweight. Seidman et al. did not make it clear that such a link had been established.

Secondly, Seidman et al. argue that it is important not to belittle the important role of adequate psychosocial support in teenage pregnancies that are frequently unintended. The research group have previously reported good pregnancy outcomes in teenagers from the ultra orthodox Jewish community of Jerusalem, where pregnancy is encouraged and the women strongly supported (Gale, Seidman, Dollberg, Armon & Stevenson, 1989). They question whether adolescents with unintended pregnancies in different cultural settings receive similar levels of support. A related issue is that of the relationship between psychosocial stresses and low birthweight/premature birth. This is discussed below in relation to persistent stressful aspects of daily life for pregnant women (Pritchard and Teo Mfphm, 1994)

Thirdly, Seidman et al. ask whether differences in the rate of prematurity could be attributed, at least in part, to poor determination of gestational age in a greater proportion of unplanned teenage pregnancies than in the pregnancies of older women.

1.4.7 Residential proximity to industrial sites

The mass media frequently draw attention to "links" between environmental pollution and adverse health outcomes. The possibility of an association between industrial pollution from major steel and petrochemical factories and adverse pregnancy outcomes has been investigated in Teesside, UK (Bhopal, Tate, Foy, Moffatt & Phillimore, 1999). Pregnant women living at varying distances from industrial sites were enrolled in the study. The authors reported that those women living close to the industrial sites were not at increased risk of adverse birth outcomes.

1.4.8 Short interpregnancy interval

The possibility of an association between short interpregnancy interval and low birthweight/preterm birth has been investigated in a Danish study (Basso, Olsen, Knudsen & Christensen, 1998). A random sample of women who had had at least two live births in Denmark between 1980 and 1992 were enrolled in the study. The authors reported that short interpregnancy intervals (less than or equal to eight months) were associated with preterm birth but not with low birth weight.

1.4.9 Employment involving use of video display units

The concern that employee exposure to video display units (VDUs) may lead to adverse health outcomes has resulted in the development of protective filters and screens. An American study has investigated whether or not the use of VDUs is associated with an increased risk of low birthweight and preterm birth (Grajewski, Schnorr, Reefhuis, Roeleveld, Salvan, Mueller, Conover & Murray, 1997).

The authors reported no increase in the risk of either low birthweight or preterm birth resulting from exposure to VDUs – irrespective of the number of hours of exposure.

1.4.10 In vitro fertilisation

A number of studies have set out to determine whether or not in vitro fertilisation (IVF) pregnancies carry a higher risk of adverse perinatal outcomes than naturally conceived pregnancies (e.g. Verlaenen, Cammu, Derde & Amy, 1995; Reubinoff, Samueloff, Ben-Haim, Friedler, Schenker & Lewin, 1997). The findings from these two studies are quite disparate despite the very similar methodologies employed.

The study by Verlaenen et al. in Belgium university hospital investigated the occurrence of perinatal complications in 140 singleton IVF pregnancies and 140 matched control pregnancies conceived naturally. The authors reported that 16 IVF pregnancies and two control pregnancies ended in the birth of premature infants. As a result, the IVF group had, on average, lower birthweights than the comparison group.

The aims of the study by Reubinoff et al., carried out in an Israeli tertiary medical centre, were largely the same as for the Verlaenen et al. study. The authors enrolled 260 consecutive singleton IVF pregnancies and 260 matched control pregnancies conceived naturally. In this study, however, the authors reported that the index and comparison groups were similar in terms of rates of preterm labour, low birthweight and small for gestational age births. Unlike the study of Verlaenen et al., Reubinoff et al. conclude that singleton IVF pregnancies do not carry an increased risk for prematurity, low birth weight or intrauterine growth retardation.

It is unclear why the difference in the finding reported by these studies exists, particularly so as they were both trying to answer the same question using similar methods. In the literature there is no metaanalysis of studies reporting on the relationship of IVF to low birthweight/premature birth. A metaanalysis or review study might help clarify this issue.

1.4.11 Work stress

The possibility of an association between stress at work and adverse outcomes of pregnancy has been investigated in a study of commercial and clerical female workers in Denmark (Brandt & Nielsen, 1992). A population of 214,108 commercial and clerical female workers in the period 1983-1985 was investigated to determine whether increasing job stress increased the risk of an adverse outcome of pregnancy. Job stress was defined in terms of increasing job demands and decreasing job control.

The authors reported an increased relative risk of spontaneous abortion and low birthweight in infants born at full term for women experiencing high job stress

No association was found between job stress and the other adverse outcomes investigated, namely, stillbirths or deaths within the first year of life, infants with congenital malformations, preterm deliveries and infants who were small for gestational age.

1.4.12 Psychosocial stress

The relationship between persistent stressful aspects of daily life and birth outcomes has rarely been studied. One study has, however, investigated the association of preterm birth and low birthweight with the psychosocial stresses of the household role for pregnant women (Pritchard & Teo Mfphm, 1994). Questionnaires were administered to 393 pregnant women attending for antenatal care in a Glasgow hospital at 20 and 30 weeks gestation. Measures of perceived difficulties with the household role and of the frequency of negative feelings about participation in the role were obtained.

The authors reported that the risks of preterm birth and low birthweight were associated with the measures of perceived difficulties at 20 and 30 weeks gestation – particularly so with the measures at 20 weeks. The frequency of negative feelings about the household role was not associated with either preterm birth or low birthweight – although it was strongly associated with the level of perceived difficulties.

It was also reported that the association between measures of perceived difficulties with the household role and preterm birth and low birthweight were maintained within categories of socioeconomic indicators (including social class, housing tenure and low income) and also with self reported smoking. The authors suggest that this indicates that the risks associated with psychosocial difficulty in the household role are independent of these other risk factors but note that smokers who experience psychosocial problems may be a particular risk.

1.4.13 Summary and conclusion

The foregoing account provides an overview of the epidemiology of low birthweight. Some of the studies cited were based in the UK, some based in other parts of Europe and some from further a field including US based urban research. It cannot be assumed, therefore that all of this research is of direct relevance to the present study or other UK based low birthweight research – as social and cultural differences are likely to be considerable.

It is clear, however, that there are many factors associated with low birthweight and that the population of low birthweight children does not constitute a homogenous group. This is an important issue and it is developed further at the start of Chapter 2. Nevertheless, there does now exist a population of children who were born at very low birthweight and the size of this population continues to increase. That this is so is largely due to changes in the care of these infants around the time of their birth. As changes in care of vulnerable infants have been introduced there has also been a responsibility falling to those charged with their care to evaluate these new practices.

1.5 Difficulties in evaluating perinatal intensive care procedures dating from the late 1960s

There are difficulties in rigorously evaluating the procedures that were established in the 1960s to treat low birthweight infants as randomised controlled trials were rare, and it is by this method that the benefit of medical treatment procedures can best be demonstrated. The statistical technique of randomised controlled trials was initially developed within agricultural research. The first human randomised controlled trials were for the development of streptomycin in the 1940s and diethylstilbestrol in the 1950s. The randomised controlled trial for diethylstilbestrol for the treatment of recurrent miscarriages demonstrated the value of such an approach (Noller & Fish, 1974). First of all it was shown that diethylstilbestrol was not an effective treatment for recurrent miscarriage. Through follow up investigation it was also found that the daughters of those women who did manage to conceive were more likely to develop vaginal carcinoma and sons, at 28 years of age, were less likely than their peers of a similar age to be married or to be in long term relationships. Had it not been for the particular methodology adopted and the long term follow up, the effects of the treatment on the offspring would have remained unknown.

Notwithstanding the advantages of randomised controlled trials a number of innovations from the 1960s become established practice without such evaluation. Indeed, there are a number of aspects of perinatal intensive care dating from this time that have never been rigorously evaluated or validated and probably never will be. This is because once a medical procedure has become well established it is then thought to be unethical to undertake a randomised controlled trial.

1.6 Evidence for the efficacy of perinatal intensive care from the 1960s

The survival rates of infants born of low birthweight, particularly those of very low birthweight and extremely low birthweight, have improved markedly in the second half of the century and particularly over the last 25 years.

Surviving infants with birthweights 1000-1500g born between 1966 and 1970 in Melbourne were enrolled in a controlled study to evaluate a range of intensive care treatment procedures (Kitchen et al., 1978). At this time intensive care measures included frequent monitoring of vital signs, glucose infusions via umbilical arterial catheter or venous catheter, sodium bicarbonate infusions in the case of acidosis, daily monitoring of biochemical parameters and blood gas analysis to enable appropriate adjustment of inspired oxygen. In a latter phase of the study, monitoring of acidosis became much more intensive and, at this stage, neonatal survival rates of VLBW infants in the study group became significantly better than those in the control/routine care group.

It became important to separate out the differential effects of the active treatment of vulnerable VLBW infants from the constant presence of highly skilled and motivated medical and nursing personnel. Neonatal care management methods in a Mansfield unit between 1963 and 1971 were characterised by a philosophical approach of high nursing standards but no medical intervention (Steiner et al., 1980). In the years immediately following this regime there was increased medical staffing, neonatal intervention and elective intubation for some infants. These innovations, however, were reported to have brought no appreciable improvement in neonatal survival rates.

A randomised trial in Melbourne evaluating elective intubation produced contrasting results. This study reported improvements in the survival of VLBW infants from 51% to 77% in the late 1970s (Drew, 1980). The differences in the findings reported in these studies may have arisen from the fact that the Melbourne study was specifically investigating the effectiveness of elective intubation whereas the Mansfield Study was investigating a number of factors and, although elective intubation was one of these, only some infants were provided with this form of intervention. There was further support for the effectiveness of neonatal intensive care practices in Buffalo (New York State) for infants of birthweight less than 800g where a tenfold improvement in survival was reported (Buckwald et al., 1984).

1.7 Early advances in neonatal intensive care in the late 1970s

New medical treatment practices for vulnerable VLBW infants in the late 1970s, around the time of the establishment of neonatal intensive care units in level III hospitals, included intermittent positive pressure ventilation, continuous positive pressure airway pressure, phototherapy and blood sampling from peripheral arteries. In the delivery room cardiotocography and scalp pH estimations were becoming increasingly routine.

1.8 Further improvements in the survival of VLBW infants resulted from the provision of neonatal intensive care units

While it has continued to be difficult to separate out the various aspects of neonatal intensive care that were introduced throughout the 1970s, the efficacy of the overall "package" of treatment measures was demonstrated in both a national cohort study in the Netherlands (Verloove-Vanhorick, Verwey, Brand, Bennebroek Graverhorst, Keirse & Ruys, 1986) and a regional study in New York (Paneth, Wallenstien, Kiely & Susser, 1982). Both these studies demonstrated that mortality rates for VLBW infants were lowest when they were born and treated in a hospital with a neonatal intensive care unit.

A meta analysis of the data from three population-based studies (Zeben van der Aa et al., 1989; Macfarlane et al., 1988; Powell et al., 1986) in the Netherlands, Scotland and England shows mortality by gestational age (Table 1.8), and these data are corroborated by data from the European Community collaborative study which reported on the outcome of pregnancies of between 22 and 28 weeks gestation (Working group on the very low birthweight infant, 1990).

Table 1.8
A meta analysis of three population-based studies in England, Scotland and the Netherlands from the 1980s; by gestational age

	Gestational Age Grouping				
	<24 weeks	24-25 weeks	26-27 weeks	28-29 weeks	30-31 weeks
Mortality	95%	86%	59%	35%	20%

The Nova Scotia Reproductive Care Programme (Peddle et al., 1983) demonstrated the success of regionalisation programmes in Canada. Declining mortality rates were reported in both the regional perinatal centre as well as in the region as a whole. There was further support from Hamilton-Wentworth county in Ontario, Canada (Horwood et al., 1982). (This study became a major Canadian longitudinal population based study led by Saigal (e.g. Saigal, Szatmari & Rosenbaum, 1989).) Studies evaluating regionalisation programmes in the USA reported similar findings: e.g. Georgia (Thompson et al., 1976); Alabama (Goldenberg et al., 1983); Colorado (Bowes, 1981).

Two studies in the USA, however, failed to demonstrate any differences in mortality rates between funded and control regions (Siegel et al., 1985; McCormick et al., 1985). Both these studies reported a similar overall pattern of declining rates of stillbirth and neonatal mortality, especially in LBW infants, but with no additional effect from the specially funded regionalisation programme. As there was already widespread centralisation of high risk deliveries by the time the studies were established, it was concluded that this was the reason underlying the lack of a special effect from the funded programme.

1.9 Advances in neonatal care of VLBW infants of the last decade

The period covering the late 1960s and early 1970s, as discussed above, was characterised by a proliferation of medical treatment procedures to support infants born at the limits of viability. The late 1970s saw improvements in the understanding of perinatal pathophysiology and the introduction of new technologies such as mechanically assisted ventilation and continuous monitoring of vital signs – usually offered in special care baby units. The 1980s and 1990s have brought further advances in neonatal care, particularly with regard to the treatment of infants with respiratory distress syndrome. It is important that longitudinal studies of VLBW and very premature infants recognise these developments as they may lead not only to improved survival rates but also to changes in longer term outcomes – either for the better or for the worse. This issue is developed in greater detail in Chapter 6 of this thesis.

1.9.1 Surfactant treatment

Surfactant reduces neonatal mortality resulting from respiratory distress syndrome by approximately 40%, furthermore it acts to reduce complications such as air leaks by approximately 60% (OSIRIS Collaborative Group (The), 1992; Morley, 1997; Soll, 1998a; Soll, 1998b). Exogenous surfactant has now been in use for over 10 years. Surfactant, when used together with antenatal steroids, is more effective than either treatment when used in isolation (Jobe, Mitchell & Gunkel, 1993).

More recently, there has been some suggestion that surfactant may be beneficial in the treatment of meconium aspiration (Findlay, Taeusch & Walther, 1996; Sim, 1996), sepsis and pulmonary haemorrhage (Sim, 1996). Surfactant has been found to be ineffective in relation to the treatment of the conditions of chronic lung disease, gross maternal haemorrhage-intraventricular haemorrhage and patent ductus arteriosis (Soll, 1996).

While there is no longer any controversy regarding the efficacy of surfactant in improving the prospects for neonates with respiratory distress syndrome there is still some debate about the timing of its administration. Surfactant has been used both prophylactically and as rescue treatment. When given as prophylaxis, surfactant is administered as early as possible, that is, as soon as the low birthweight baby has been intubated – ideally within the first few breaths of life. When given as rescue treatment, surfactant is administered a few hours after birth. Randomised controlled trials indicate that prophylaxis is more effective than rescue treatment (Soll & Morley, 1998) although for larger infants who develop respiratory distress syndrome later administration, even up to 72 hours after birth, can still be beneficial (Speer, Robertson, Curstedt, Halliday, Compagnone, Gefeller & Harms, 1992).

1.9.2 Extra-corporeal membrane oxygenation

Extra-corporeal membrane oxygenation (ECMO) involves using equipment similar to that used for cardiopulmonary bypass to oxygenate blood outside the body. ECMO can be used to provide cardiovascular support to infants who have a birthweight of not less than 2000g. It is most effective in the treatment of neonates with persistent pulmonary hypertension and meconium aspiration.

The UK ECMO study (UK Collaborative ECMO Trial Group, 1996) reported upon a two year randomised trial. 185 infants were enrolled over the two years of the study. Ninety three infants were allocated to the ECMO arm of the trial of whom 30 died (survival = 68%). Of the 92 allocated to the conventional care arm of the trial 54 died (survival = 41%). The trial was, therefore, discontinued, although follow up of these infants continues.

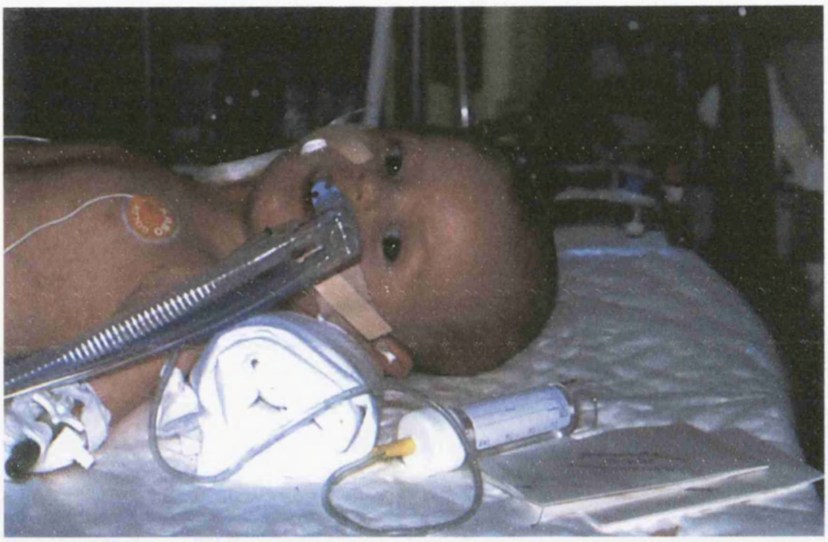

Figure 1.9.2 Infant receiving extra-corporeal membrane oxygenation

With regard to longer term outcome, quality of survival remained a concern. While the UK ECMO trial reported that 45 of 62 (73%) infants appeared to be developing normally at one year follow up, the international registry records that 17% of infants treated with ECMO suffer intracranial haemorrhage or infarction (Soll, 1996). A five year follow up study of infants treated with ECMO demonstrates a high prevalence of major disability (Glass et al., 1995). Of the 103 infants treated with ECMO, 17% were reported to have major disability. Deafness appears to be a particular worry and concern was expressed about challenging behaviour and scholastic failure in a higher percentage.

A further assessment of the UK ECMO children at four year is to be presented shortly and a seven year follow up is now underway.

1.9.3 Inhaled nitric oxide

Persistent pulmonary hypertension, a commonly occurring condition in low birthweight infants, had proven difficult to treat effectively before the introduction of inhaled nitric oxide treatment. A range of injectable vasodilators had been evaluated without any randomised controlled trial evidence to show improved outcome from any of them. The difficulty in establishing nitric oxide as a treatment was in the development of a suitable delivery system. Nitric oxide gas rapidly oxidises to higher oxides of nitrogen in the presence of oxygen. Nitrogen dioxide, for example, is a toxic gas and one of the constituents of car exhaust fumes that has been extensively studied. Nitric oxide, therefore, has to been administered directly at the patient manifold of the circuit to minimise the contact time between the gas and oxygen. A randomised controlled trial is currently being piloted in the UK with longer term follow up planned. Inhaled nitric oxide has become an established treatment for persistent pulmonary hypertension. Where persistent pulmonary hypertension is complicated by severe lung disease, however, inhaled nitric oxide is ineffective unless given in conjunction with high frequency oscillation ventilation (Kinsella, Truog, Walsh, Goldberg, Bancalari, Mayock, Redding, deLemos, Sardesai, McCurnin, Moreland, Cutter & Abman, 1997) and where it is a component of respiratory distress syndrome inhaled nitric oxide is of no benefit (Subhedar, Ryan & Shaw, 1997).

Figure 1.9.3 Infant receiving inhaled nitric oxide

1.9.4 High frequency oscillation ventilation

High frequency oscillation ventilation (HFOV) involves exposing the lungs to positive and negative pressures alternately at very fast rates – usually around 10 Hz (10 cycle per second). Special equipment in the form of oscillators is required to achieve ventilation at such high frequencies. HFOV has been shown to save infants with severe respiratory distress syndrome where conventional ventilation and surfactant treatment has failed (Clark, Yoder & Sell, 1994).

In the Provo trial, 125 infants of less than 35 weeks of gestation with respiratory distress syndrome who had received surfactant were randomly allocated to HFOV or to conventional ventilation. There were more survivors without chronic lung disease at 30 days in the HFOV group (Gerstmann, Minton, Stoddard, Meredith, Monaco, Bertrand, Battisti, Langhendries, Francois & Clark, 1996).

1.9.5 Prophylaxis against group B streptococcal infection

The leading cause of infection in neonates is group B streptococcus. Infection with the group B streptococcus can lead to lengthy hospitalisation. Of those who survive, a third will have permanent sequelae. Intrapartum antibiotics given prophylactically have been shown to be effective in reducing the occurrence of group B streptococcal disease. A meta analysis has shown a 30 fold decrease in the occurrence of early onset group B streptococcal infection when intrapartum penicillin is administered as prophylaxis (Allen, Navas & King, 1993).

1.9.6 Summary of recent advances in the care of very low birthweight neonates

Since the advent of special care baby units in the late 1970s, further advances have been made that have resulted in improved survival rates. The limits of viability appear to have become fairly well established at around 500g birthweight or 24 completed weeks of gestation. Recent advances have not brought about a reduction in these limits of viability, other than in sporadic cases, but they have resulted in increased survival rates for babies born at the limits of viability.

For a more comprehensive account of current advances in the care of very low birthweight infants the reader is referred to recent review (Rennie & Bokhari, 1999).

The question that follows on from increased survival rates of infants born at the limits of viability is that of both major and less serious sequelae and whether these are transient or permanent. This question is, in essence, the theme of this thesis and it is one that will be revisited time and again in the following pages.

1.10 Morbidity in VLBW infants

The focus of low birthweight research throughout the 1960s and 1970s continued to be the perceived need to report on the survival of VLBW and ELBW infants (Stewart & Reynolds, 1974; Bhat et al., 1978; Hirata et al., 1983) but increasingly on the prevalence of major sequelae, especially cerebral palsy (Drillien, 1961, 1964; Wiener, 1965, 1968; Rubin et al., 1973; Pape et al., 1978). A letter in the British Medical Journal (Brown, 1977) gave greater urgency to this strand of investigation when, responding to an article on improved survival rates of very small babies (Gordon, 1977), he asked how far this was a '...triumph of neonatal paediatrics or a social and family disaster'. Brown suggested that having actually created a social and family disaster the medical fraternity, especially neonatologists and obstetricians, were now happy to pass the responsibility for supporting these children and their families on to others – increasingly so as the seriousness of the problems these surviving children were experiencing later in life was becoming clear.

As Brown's letter to the editor of the British Medical Journal indicates, the risk of surviving VLBW infants being born with impairment, disability or handicap became a major concern as mortality rates fell. Morbidity is more difficult to define and measure than are mortality rates. The methodological problems are greater than is the case with mortality and the data available are less precise, thus it is not surprising that the evidence for an increase or decrease in neurodevelopmental impairments associated with falling mortality rates remained controversial.

While the decline in birthweight specific mortality was beyond doubt, it could not be shown categorically that there was a concomitant fall in the rates of major morbidity in VLBW survivors. The best indications from population based studies suggested that there was no increase in major morbidity (e.g. Grögaard et al., 1990; Powell et al., 1986; Saigal et al., 1982). However, there was by no means a consensus on this issue. Other population studies (e.g. Grether et al., 1992; Dowding & Barry, 1990; Hagberg et al.,1989) found an association between birthweight and cerebral palsy, although they tended not to find an association between birthweight and severity of functional impairment. Some hospital based studies (e.g. O'Shea et al., 1992) also found this association. Stewart, in her survey of the world literature on VLBW infants born between 1946 and 1977, reported falling neonatal mortality rates but no corresponding rise in the rates of neurological impairments (Stewart et al., 1981). Her results, however, may have been overly optimistic in that she had a selection bias of hospital based studies as opposed to population based studies and she employed arbitrary definitions for the labelling of impairments.

1.11 Neonatal intensive care as measured by prevalence of cerebral palsy in VLBW infants

Despite the controversy regarding whether rates of major sequelae were increasing with falling mortality rates of VLBW infants, there was general agreement that an association between the two did exist. It became customary to use the population prevalence of cerebral palsy to determine the impact of aggressive intervention.

A seminal paper in mid-1880s discussed the relationship between abnormal parturition, difficult labour, premature birth and asphyxia neonatorum on the physical and mental condition of the child (Little, 1862). Since this time the relationship between these perinatal conditions and cerebral palsy has come to be considered an established fact. Thus, cerebral palsy was taken to be a crude but effective measure of outcome of neonatal intensive care. This was based principally on the assumption that cerebral palsy resulted from neonatal hypoxia. However, there is evidence to suggest that some VLBW children have prenatally compromised central nervous systems and it is this rather than neonatal hypoxia that is responsible for cerebral palsy in these children (e.g. Torfs et al., 1990; Dennis et al., 1989; Stanley, 1989; Emon & Golding, 1989). As this view has become more widely accepted the use of prevalence of cerebral palsy as a measure of outcome of neonatal intensive care has come to be regarded as a less valid measure than had previously been supposed.

The unresolved issue of progressively falling mortality rates associated with static or increasing rates of cerebral palsy still exists. What can be said, however, is that if there is an increase in the rates of cerebral palsy then it may be due in part to a failure to maintain optimum neonatal conditions, but it may also be due to increasing survival of prenatally neurologically impaired infants or to the possibility that the true prevalence of cerebral palsy has been established by fuller and longer-term follow-up

(Pharoah et al., 1990; Hagberg et al., 1989; Riikonen et al., 1989; Stanley & Watson, 1988; Johhson et al., 1987; Saigal et al., 1984).

1.12 Minor neurological dysfunction and longer-term outcomes

What is of particular concern is the long term outlook for children with post-natal morbidity whether it is major impairment or lesser, more subtle impairment. This thesis has as its focus the cognitive ability, motor skills and educational attainment of VLBW infants. In many ways it is those children who experience lesser morbidities who are of greatest interest as they may be judged to be developing normally in their early years but go on to experience difficulties later on – as the demands placed upon them as they progress through their school years increase. This group is of interest at an additional level, that is, in terms of the demands these children will place on the provision of special education and therapeutic services.

The following chapter provides a review of the extensive body of literature on outcome studies of VLBW infants. The literature is vast, although the review has been structured in such a way as to make it as manageable and accessible to the reader as possible. Following the introductory section the main body of the chapter is organised according to areas of development and methodology. The first half of the review is concerned with cognitive and scholastic outcomes and the second half with neuromotor outcomes. The specific hypotheses that are central to this thesis are presented at the end of each section. There is, in addition, a further level of organisation. The review of each developmental area is considered in terms of the contributions to the literature from hospital centre or unit based studies and from the more methodologically sound population based studies.

Chapter Two

Low Birthweight Research – Cognitive Development, School Attainment and Neuromotor Competence: A Review of the Literature

Section 1 Context, Scope and Theoretical Considerations

2.1 Scope of the review of the literature on low birthweight research

"A fundamental concept in understanding the large and often confusing literature on LBW and later neurobehavioral development is that LBW may have many different aetiologies, with varying relative frequencies in different populations, which probably have different degrees of associated risk for impairment of later development." (Sommerfelt, 1998, p.1). A daunting task indeed then to do justice to a review of the immense body of literature on low birthweight research. It is a field of research, however, that must be rigorously pursued. Doctors, nurses and associated professionals are developing techniques that enable ever greater numbers of infants of low birthweight and short gestation to survive – effectively extending the limits of viability. Children who, two decades ago, would not have been born alive or who would not have survived the neonatal period are now entering the primary and secondary education systems. It is important to understand the longer term sequelae of low birthweight in order that any particular needs of such children can be recognised and adequately addressed. As Sommerfelt correctly acknowledges, the low birthweight population does not represent a homogenous group – there are many reason why an infant may be born of low birthweight. Furthermore, the research approaches that have been adopted, as will be discussed in detail below, have been many and varied. This makes the tasks of establishing consistencies in research findings all the more difficult.

2.1.1 Investigations of the psychological domains of development in low birthweight children

As far as the psychological development of low birthweight children is concerned it has been suggested that there are four principle domains that can be considered (Wolke, 1998). He suggests the four domains of psychological development are represented by (i) cognitive functioning, (ii) behaviour and emotional status, (iii) social functioning and (iv) scholastic progress. The scope of this thesis is limited to the first and last of these domains of psychological development. Data were also collected in relation to emotional status and social development and the findings from this aspect of the study have been reported previously (e.g. Hall, 1994).

An area of development that would not be considered psychological in nature is that of neuromotor functioning. Neuromotor competence is, however, important in terms of a child's ability to function within these psychological domains. Included within the scope of this thesis is, therefore, a detailed study of neurological functioning and motor competence. In the last analysis, the aim of this thesis is to give consideration to the educational needs of children at risk, in this case as a result of being born very low birthweight and at early gestation. It seems to make sense, and much of the literature described below supports the notion, that neurological functioning and motor competence are just as important to educational success or failure as is cognitive ability.

2.2 Low birthweight research and psychological theories of development

2.2.1 Psychological theories of development in the context of VLBW research

It is important to acknowledge at the outset that research on infants that are of low birthweight inevitably means that almost all were born at early gestation. Experimental research has revealed a great deal about processes of both growth in the developing brain (e.g. cell proliferation, migration and establishment of connections) and, more recently, subtractive processes (e.g. neuron loss and axon retraction). These subtractive processes are as much a part of brain development as growth processes. Some of these subtractive processes especially neuron loss occur at very early gestation, whereas others occur nearer to term. These processes have been discussed in relation to perinatal brain damage (Janowsky & Finlay, 1986) and it is suggested that several aspects of early brain damage in children born at early gestation can be accounted for by alterations in these processes - with the neocortex and cerebellum being particularly susceptible.

Psychological theories of development are discussed below and, in this regard, such theories are inevitably based upon children of appropriate birthweight and length of gestation. It may be that the brain of a neonate born at early gestation is fundamentally different to that of an infant born at full term of appropriate birthweight – in terms of aspects of its organisation such as synaptic connectivity – and this may continue to be the case beyond the neonatal period. Thus, while psychological theories of child development might apply to the child born at full term of appropriate birthweight it cannot be assumed that they will apply equally to the low birthweight child born early. This issue is revisited and developed in Chapter 6 of this thesis.

2.2.2 Medical versus psychological approaches to VLBW research

Research investigating the survival and longer term outcomes of low birthweight infants has been very much the domain of the medical profession. This comes as no surprise as the methods, techniques and specialised equipment that have enabled babies nearer to the limits of viability to survive have been developed by the medical and allied professions.

Quite rightly the medical profession has set up research projects that seek to evaluate the effectiveness of its neonatal care methods. While other professionals such as psychologists, sociologists, economists and statisticians have often participated in study groups, research projects in this field have generally been led by the medical profession. A consequence of this is that research projects have often been set up to answer quite specific questions. There is a place, however, for a broader based research approach that tests a range of hypotheses within a given area of investigation and that is set within a theoretical context whereby the findings are related to theory and practice.

Two doctoral theses from members of the Liverpool Maternity Hospital Study Group demonstrate this difference in approach (Powls, 1997; Botting, 1997). Powls, a medical man, presented his MD thesis in terms answering specific research questions about motor development and visual impairment in VLBW children at early adolescence. He set out his study in relation to previously published research but not to theory. Furthermore, he had relatively little to say about the implications of his research for medical practice. Botting, in her PhD thesis, generated and tested a considerably wider range of hypotheses and, in addition, related her research to developmental theory. Botting, a psychologist, undertook research concerning the psychological outcomes of VLBW children at adolescence. The main outcome measures of interest were prevalence of conditions such as anxiety, attention deficit hyperactivity disorder, depression, eating and sleeping disorders, and behavioural and emotional disorders. She discussed her findings in relation to attachment theory and social learning theory.

There are a number of strands of investigation to the present study. The main areas of interest are the cognitive, scholastic and motor outcomes of VLBW children at eight years of age. In addition, issues such as gender and appropriateness of birthweight for gestational age are considered in relation to outcome and a number of methodological issues are considered in detail. An attempt is made to set the study within the context of psychological developmental theory. The following section provides the reader with an introduction to theories of cognitive development in childhood.

2.2.3 Piaget's theory of logical development in childhood

Developmental theorists such as Jean Piaget, Heinz Werner, Jerome Bruner and Lev Semenovich Vygotsky have observed that children seem to progress through systematic stages of thought organisation. While all these developmental theorists have made an impact on our understanding of child development, the theory of cognitive development that dominated developmental psychology in the 20th century, and continues to do so, is that of Jean Piaget. His is an epistemological theory concerned with the child's acquisition of knowledge.

Piaget's theory, often referred to as "Piaget's theory of logical development in childhood", is very much rooted in his background as a biologist. His initial interest was in the adaptation of organisms to their environment. This evolved into an interest in child development and, in particular, the child's acquisition of knowledge. Thus, just as biologists have a fundamental interest in the origins of life Piaget developed a fundamental interest in the origins of knowledge.

Piaget's was the first theory of child development to provide a comprehensive account of child development form birth to adolescence. He suggested that there are two processes that underpin cognitive development, namely, "accommodation" and "assimilation". For Piaget, accommodation and assimilation are complementary processes. Accommodation is the process of adapting cognitive schemes for viewing the world, in other words, adapting general concepts to fit reality. The complementary process of assimilation involves interpreting experience in terms of current cognitive schemes. Piaget suggested that when one cognitive scheme becomes inadequate for making sense of the world it is replaced. The organism's aim is to achieve cognitive equilibrium. He also suggests, however, that any cognitive equilibrium is only partial and, therefore, every existing equilibrium must evolve towards a higher form of equilibrium. In the case of a child, this is towards a more adequate form of knowing. This process of evolution, from one equilibrium to a higher equilibrium, drives cognitive development. This is similar to Werner's dialectical theory of child development whereby the process of "thesis › antithesis › synthesis" is believed to drive cognitive development.

2.2.3.1 The "stage" nature of Piaget's theory

There are, according to Piaget, three occasions between infancy and adolescence when a major overhaul of current cognitive schemes takes place. His is a stage theory of cognitive development. The three major stages in cognitive development correspond to three successive forms of knowledge, that is, children are believed to think and reason in a different way at each of these three stages.

The three stages (and the ages at which they are supposed to occur) are:

1. The sensory motor period (birth – two years)
2. The period of concrete operations (seven –11 years)
3. The period of formal operations (11/12 years onwards)

(The period from approximately two – to seven years of age is regarded by Piaget as the stage of pre operations. The reader is referred to section 2.2.3.1.2 below.)

It is beyond the scope of this thesis to provide a comprehensive account of all aspects of all stages of Piaget's theory of logical development in childhood. Nevertheless, the reader is provided with an overview of Piaget's theory and the following sections are designed to outline the structure and sequence of the three stages and their associated substages.

2.2.3.1.1 The sensory motor stage

The idea that thought develops from action is central to Piaget's theory of cognitive development. In Piaget's view there is practical logic of relationships and classes in terms of sensory motor action – "a logic of action". This is a necessary precursor of the representational logic of relationships and classes that emerges at the concrete operational stage.

Infants are born with many means of interacting with their environment. There is an extensive body of research literature that demonstrates that the sensory systems of babies are functioning at birth. More recent research has demonstrated that the sensory motor systems of the fetus are active in utero, for example, thumb to mouth actions have been observed. Therefore, the latter stage of in utero existence could be regarded as a preparatory phase for the infant. There are a number of comprehensive reviews of this body of literature (e.g. Bremner, Slater & Butterworth, 1997). Thus, motor responses such as sucking and grasping are ready for use at birth. For Piaget, although babies are born knowing nothing about their worlds, they have the prerequisites to know everything about their worlds. The sensory motor experiences of even the newborn infant in the everyday world allow it to gain knowledge of the world and set up hypotheses about it. Piaget views the infant as relentlessly interpreting and reinterpreting perceptual information in the light of its hypotheses.

2.2.3.1.1.1 Sensory motor substages

The sensory motor stage for Piaget comprised six sub stages of development:

(i) modification of reflexes, for example, the infants modifies its sucking reflex to fit the contours of its mother's nipple.

(ii) primary circular reactions – the infant engages in repetitive behaviour patterns, for example thumb sucking, which recreates sensory experience.

(iii) secondary circular reactions – the infant engages in repetitive behaviour that involves the outside world, for example, banging a toy or shaking a rattle.

(iv) coordination of circular reactions – the infant is able to coordinate a series of behaviours to achieve a goal. This is sometimes referred to as goal orientated behaviour or means-end behaviour.

(v) tertiary circular reactions – the infant can now conduct different trial and error explorations in order to determine the result of certain actions. For Piaget this is hypothesis testing behaviour and, in turn, leads to the discovery of spatial and causal relationships.

(vi) interiorisation of schemes – the infant, having reached this final stage of sensory motor cognition, is now able to anticipate the consequences of certain actions. There is no longer any need for trial and error exploration, the infant, is able to work out the sequences of actions required to attain a certain goal prior to performing the actions themselves.

The ways in which sensory motor experience define the subjective world of the infant are described no more eloquently than by Piaget himself:

> "The infant is not content to suck only when he nurses; he also sucks at random. He sucks his fingers when he encounters them, then whatever object may be presented… and finally he coordinates the movement of his arms with the sucking until he is able to introduce his thumb into his mouth systematically… In short… his initial behaviour can be described by saying that for him the world is essentially a thing to be sucked. In short order, the same universe will also become a thing to be looked at, to listen to, and, as soon as his own movements allow, to shake." (Piaget, 1967, p.9)

Piaget went on to describe that sensory motor development can be observed in different domains of sensory motor cognition, for example, spatial relationships, motor cognition, time, causality and the conception of object permanence. There are a number of texts that provide a comprehensive account of Piaget's theory, (e.g. Butterworth & Harris, 1994).

Bruner has pointed out that sensorimotor thinking does not end in early childhood, indeed, it is never totally abandoned as there are always concepts that can be represented best of all through action – rather than through words or images. Bruner's term for this notion is "enactive representations".

> "By enactive representation I mean a mode of representing past events through appropriate motor response. We cannot, for example, give an adequate description of familiar sidewalks or floors over which we habitually walk, nor do we have much of an image of what they are like. Yet we get about them without tripping or even looking much. Such segments of our environment – bicycle riding, tying knots, aspects of driving – get represented in our muscles, so to speak." (Bruner, 1964, p.2)

2.2.3.1.2 The period of pre operations (2-7 years)

There is a period of childhood, from approximately two to seven years of age, that does not correspond to any of Piaget's three stages. Piaget's own investigations, sometimes based on observations of his own children, led him to believe that a full symbolic understanding of the properties and relationships of concrete objects came about only gradually. Between two and seven years of age children's solutions to problems concerning objects and their relationships, for example, inclusion and conservation problems are characterised by pre operational thought. The pre operational child approaches problems in an "egocentric" fashion, that is, the child perceives and interprets the symbolic world in terms of the self. "Centration" and "lack of reversibility" are also characteristics of pre operational thought. Centration refers to the tendency of the pre operational child to attend to only to one aspect of an object or situation. Lack of reversibility refers to a tendency to use symbols or representations in an irreversible fashion, that is, the child is unable to reverse a series of steps of reasoning or to reverse a series of events. The internalisation of, for example, basic arithmetic operations such as addition and subtraction on concrete objects leads to the symbolic representation of the formal properties of whole numbers. The recognition of the reversibility of, for example, $2 + 2 = 4$ simultaneously implying $4 - 2 = 2$ is, for Piaget, a critical feature of concrete operational cognition. The pre operation child, however, is seen as pre logical with a subjective, self centred understanding of the world.

2.2.3.1.3 Concrete operational thought

Piaget believed that the child's developing logical insights concerning the symbolic understanding of objects led to the development of concrete operational structures such as classification and conservation. Once the child reaches the stage of concrete operational thought there is a diminishing of egocentricity, centration and lack of reversibility.

There are for Piaget, four principles that characterise operational thought, namely, "closure", "reversibility", "associativity" and "identity". He believed that mathematical logic could be used to describe the psychological reality of the structures developed by the child.

(i) closure – any two operations can be combined to form a third operation, for example, all boys and all girls equals all children; $6 + 2 = 8$.

(ii) reversibility – for any operation there is an opposite operation that cancels it, for example, all boys plus all girls equals all children, but all children except all boys equals all girls; $6 + 2 = 8$ and $8 - 6 = 2$.

(iii) associativity – when three operations are combined it does not matter which two are combined first. In other words, the same goal can be reached by different routes, for example, all adults and boys plus all girls equals all adults plus all boys and girls; $(1 + 4) +2 = 1 + (4 + 2)$.

(iv) identity – this is a "null" operation and is performed when any operation is combined with its opposite, for example, all human beings except those who are human beings equals nobody; $5 - 5 = 0$.

Most recent research on pre operational and concrete operational thought has been less concerned with Piaget's focus on mathematical groupings but more on whether logical concepts such as conservation are present at an earlier age than he supposed.

2.2.3.1.4 Formal operational thought

Children are now no longer reliant on the concrete – they can think about abstractions. There is an emerging ability to take the results of concrete operations and generate hypotheses about their logical relationships. Piaget describes this level of reasoning as “operating on operations” or “second order” reasoning.

Formal operational thought is, for Piaget, scientific thought. The attainment of formal operations allows the child to represent alternative hypotheses and their deductive implications. Piaget described formal operational reasoning in terms of the ability to apply a formal system such as propositional logic to the elementary operations concerning classes of objects and their relationships, for example:

	All A are B		All Poodles are Dogs
	All B are C		All Dogs are Animals
Therefore	All A are C	Therefore	All Poodles are Animals
or			
	All A are B		All Poodles are Dogs
	All B are C		All Dogs are Animals
Therefore	Some C are A	Therefore	Some Animals are Poodles

2.2.3.2 The relationship of Piagetian developmental theory and VLBW research

Piaget’s theory of psychological development offers an account of the development of the “average” child – the child who has had a full term of intrauterine life, in an intrauterine environment of good quality and who is born at an appropriate birthweight for this full gestation. Piaget’s theory has stood the test of time and it continues to form the basis of considerable empirical research in the field of child development (e.g. Munakata, McClelland, Johnson & Siegler, 1997).

What of the relevance of Piagetian theory to the child who has missed out on the last ten weeks or so of gestation, who is born at very low birthweight and who may be of a size disproportionately small for its gestational age? In relation to the population of children in the present study, it may be that sensory systems are not functioning as well at birth (even excluding those with major neurosensory impairment) as would be the case in heavier birthweight infants born at full term. Similarly VLBW, preterm infants are likely to be immature in terms of their neuromotor development. As a result, programmed motor responses such as sucking and grasping may be delayed or disordered. If both sensory and neuromotor abilities are absent, delayed or somehow different at birth in such children then they will not have the same range of means to interact with their world as their heavier birthweight peers. If Piaget sees these basic responses as the means by which babies gain knowledge of the world and build up hypotheses about it, then VLBW, preterm infants will be disadvantaged. The infant, from Piaget's point of view, is seen as busily interpreting and reinterpreting sensory information in the light of its hypotheses. These hypotheses, in turn, are drawn from the babies' sensory motor experiences in the world.

It might be postulated that intrauterine growth retarded VLBW (small for gestational age) infants should be even more disadvantaged in this regard than their appropriate for gestational age VLBW counterparts – on the assumption that the uterine environment is not optimal. This is not a new area of research – some researchers have been investigating small for gestational age VLBW infants for a number of decades (e.g. Ounsted & Ounsted, 1973). It is, however, an area of investigation that is growing as far as intrauterine growth retardation early in gestation is concerned. Growth retardation generally occurs in the third trimester and, therefore, it has been easier to investigate in full term infants. However, as a result of increasing numbers of surviving infants who are extremely small and extremely premature there are now sufficient numbers of small for gestational age infants born in the second trimester to allow for rigorous investigation.

The sensory motor period lasts from birth to approximately two years of age. VLBW children with or without profound sensory impairments and severely impaired neuromotor functioning will not have the means with which to interact with their world at birth – the tiny infant in the incubator clearly does not have the same quality of interaction with its world as a baby born at full term of appropriate birthweight. This may be even more true for intrauterine growth retarded infants. There is likely to be a delay in starting the whole process of interpreting perceptions and hypothesis constructing. Furthermore, as mentioned above there is research evidence of sensory motor activity prenatally. If the uterus in late gestation is regarded as a preparatory environment where sensory motor activity occurs then it follows that infants born at early gestation will be disadvantaged and, arguably, all the more so if the uterine environment is less than optimal – resulting in intrauterine growth retardation. The sensory motor period, therefore, may well be of longer duration for infants born at early gestation, especially those who are small for gestational age, than is the case for infants born at full term or who are of appropriate birthweight for gestational age.

Researchers in the field of low birthweight/preterm birth follow up research will often correct the ages of their study infants for the degree of prematurity (this issue is discussed in more detail in Chapter 3). This is especially the case for follow up studies carried out within the first one to two years. It may be the case that by the time an appropriate for gestational age VLBW infants reaches the age at which it would have been born if gestation had gone to full term, its sensory and neuromotor systems are functioning satisfactorily and the sensory motor stage of cognitive development can commence. Whether or not this is so, it may be different in the case of intrauterine growth retarded infants.

Piagetian theory, if it applies to this population, would suggest that VLBW infants, without major sensory or neuromotor impairment, are likely to be delayed in reaching the pre operational stage but their cognitive development should, thereafter, proceed unhindered unless there are other factors at play. Should longer term follow up research show that children who were VLBW infants experience increasing delay when compared with children who were of heavier birthweight, then this would suggest that delay in reaching, and the course of, the sensory motor stage is an over simplistic explanation. It would suggest that there are other factors at play and this, in turn, might suggest a poorer prognosis for VLBW children. Clearly follow up of VLBW children through the primary school years and beyond will be required to clarify this issue.

Considering the longer term outcomes of VLBW infants in relation to developmental theory does not, of course, tackle the question of the underlying mechanisms involved, for example, brain organisation at different stages of gestation, as referred to above, and the process of myelination. It may be that Piaget's theory of psychological development in childhood, or any other existing theory of psychological development for that matter, does not apply to this population because VLBW children are different to the population upon which these theories were based. This issue will be reconsidered and developed in Chapter 6 of this thesis.

2.3 Origins of the literature on the longer term outcomes of the "new survivors" of neonatal intensive care

Very low birthweight is the most important known risk factor for infant mortality in general and neonatal mortality in particular (Shah & Abbey, 1971; Drillien, 1974; Eberstein & Parker, 1984; Cramer, 1984; McCormick, 1985; Tompkins, Alexander, Jackson, Hornung & Alterkruse, 1985; Rogers, 1989). The earliest study to investigate the consequences of surviving low birthweight/prematurity on later development appeared in the second decade of the twentieth century (Ylöppo, 1919). This study and the few others from the first half of this century (refer to Table 1.2) appeared to suggest that those surviving infants of low birthweight/prematurity subsequently experienced a variety of developmental problems. These studies, however, employed methodologies that were flawed as they tended to be carried out retrospectively and were based on small study groups. Objective, standardised measures of assessment were not used and reports of outcome tended to be based upon the clinical impressions of the medical practitioners involved in the care of the infants concerned. The methodological flaws that render these early studies, at best, inconclusive were discussed in the literature at the time (Benton, 1940).

Ever since the advent of neonatal intensive care, follow up studies have become more sophisticated. They have tended to be prospective in nature, seeking to explore the relationship between early risk factors and later outcome in a more systematic fashion. The earliest studies of the neonatal intensive care era, reporting falling mortality rates for very low birthweight infants, appeared in the literature in the late 1970s and early 1980s (Thompson & Reynolds, 1977; Kitchen, 1978; Hack, Caron & Merkatz, 1979; Pharoah & Alberman, 1981; Stewart, Reynolds & Lipscomb, 1981; Shapiro, McCormick, Starfield & Crawley, 1983; Hack, Caron, Rivers & Fanaroff, 1983). There was a proliferation of follow up studies throughout the 1980s and a review paper appearing at the end of the decade reported that more than 1000 had been published (Aylward and Pfeiffer, 1989).

2.4 Very low birthweight and major sequelae

A study from the early 1980s surveying the world literature on the survival and morbidity of low birthweight infants from the mid 1940s until the late 1970s illustrates clearly the pattern of change in outcome through the transition to the neonatal care period (Stewart et al., 1981). The reviewers encountered the perennial problem of comparing studies that are disparate in nature, not least in terms of the dissimilar nature of the cohorts. Nevertheless, notable consistencies in outcome were observed between studies.

The early studies reviewed, covering the period up until the 1950s, reported high rates of both mortality and serious impairment. The review, in fact, dealt only with major sequelae such as cerebral palsy, hydrocephalus, mental retardation (i.e. I.Q.<70) and severe sensory impairment which collectively were referred to as "major handicap". An increase in survival rates was reported following on from the introduction of more involved and invasive neonatal care techniques, but this was accompanied, at least in some centres, by a concomitant increase in major handicap (e.g. Schechner, 1980). In the latter period, covering the years through to the late 1970s, a threefold increase in the rate of healthy survivors was reported with the rate of major handicap levelling off at 6% to 8%.

This pattern was reflected in a subsequent major review of the literature two years later (Kopp, 1983). In her review, Kopp reported on 32 studies covering the 1960s through to the mid 1970s. In summary, she reported less serious major sequelae and higher I.Q. test scores amongst the preterm infants than would have been observed a generation earlier. It does not necessarily follow, however, that it was advances in neonatal care techniques that brought about these changes, I.Q scores, for example, tend to increase over time. Furthermore, Kopp did not separate out studies reporting on, for example, extremely preterm, growth retarded or neurologically impaired infants. She does acknowledge, however, that there is considerable variation in outcome in terms of the type of infant being considered.

A trend not observed in the earlier major review (Stewart et al., 1981) but which had become apparent in Kopp's study was a gradual shift of focus whereby increasing attention was being paid to lesser morbidities, especially minor neurological impairment and the consequences for subsequent school attainment. Those studies that had followed VLBW children through to their school years were, in general, reporting lower attainments in basic curricular areas such as literacy and numeracy despite general conceptual ability falling within the normal range (+ or - 1 SD) (e.g. Kitchen, Ryan, Rickards, McDougall, Billson, Keir & Naylor, 1980).

Kopp also made particular mention of the inadequate reporting of sample characteristics, especially social class. She noted that while many studies fail to show any clear relationship between severe perinatal events and outcome, those that describe sample characteristics seem to indicate that it is socio economic status rather than perinatal events that is the best predictor of outcome. (This point is related to the methodological issue of hospital based versus population based studies. This is an important issue in terms of the validity of reported findings and in terms of comparing the findings of different studies. The question of hospital based versus population based studies is one that will be revisited many times in the following literature review and it is discussed in detail in Chapter 3.)

A study group from the University of Washington compared mortality rates and rates of neurodevelopmental morbidity amongst infants of birthweight less than 800g from its own neonatal intensive care unit (NICU) over a 15 year period (La Pine, Jackson & Bennett, 1995). The authors reported upon the survival and neurodevelopmental outcome of 210 infants admitted to their neonatal intensive care unit between 1986 and 1990 and compared these outcomes with those from two earlier cohorts of ELBW infants (1977 to 1980 and 1983 to 1985) also admitted to their NICU.

Annual admission rates were reported to have doubled from 1977 to 1990. Neonatal survival was 49% for births between 1986 and 1990 whereas survival had been 20% for the 1977 to 1980 cohort and 36% for the 1983 to 1985 cohort. It was reported that the greatest increase in survival was for infants with birthweights less than 700 grams.

Female survival was 20% higher than male survival across each of the three periods. The prevalence of major neurodevelopmental impairment did not vary significantly between the three cohorts (19%, 21% and 22% respectively) nor were there significant differences between mean cognitive test scores across the three time periods.

La Pine and colleagues concluded that, despite progressive increases in neonatal survival from the mid 1970s to early 1990s, there has been no increase in the prevalence of neurodevelopmental morbidity. They note that these findings from their own NICU, characterised by a protocol of aggressive intervention throughout the 15 year period, cannot necessarily be generalised to other settings.

The continuing lack of consensus regarding the question as to whether or not prevalence of major developmental sequelae increases with increased survival rates is apparent from the contributions to the literature at that time. A number of studies reporting on cohorts from the early days of neonatal intensive care reached the conclusion that increased survival through aggressive intervention in the ELBW population is accompanied by increased rates of neurodevelopmental morbidity such as cerebral palsy, sensory impairment and mental retardation (e.g. Schechner, 1980; Drillien, 1985; Collin et al., 1991; Ross et al., 1991; McCormick, 1993). Others were opposed in their argument, suggesting that aggressive intervention in this population is associated not only with lower rates of neonatal mortality but also with improved neurodevelopmental outcome (Stewart & Reynolds, 1974; Driscoll et al., 1982; Horwood et al., 1982; Victorian Infant Collaborative Group, 1991).

2.4.1 Bias in the reporting of mortality statistics

An issue not mentioned in any of these early reports but one that has recently been highlighted relates to errors that can occur when birthweights are being registered and how these can cause bias in the reporting of mortality statistics (Anand & Pharoah, 2000). The authors studied the death certificates of all twins born between 1993 and 1995 who did not survive. They found that in 2.5% of cases the registered birthweight was not stated and in others they discovered miscoding errors. Anand and Pharoah also reported that errors for infants of birthweight less than 500g and greater than or equal to 3500g were most evident. While it is possible to see why errors might occur in ELBW infants, for example, misclassification of liveborn infants as stillborn, it is harder to explain why more errors were evident in the higher birthweight group. The authors suggest that the bias arising from these errors should be taken into consideration when morality rates and their trends are being interpreted.

2.5 The "new survivors" of neonatal intensive care

Infants who were VLBW and/or very premature and who were being investigated in relation to their longer term outcomes were described as the "new survivors" of neonatal intensive care. That is to say, these children represented a population that was new to the medical world – one that did not exist prior to the 1970s and one that clearly demanded rigorous and thoroughgoing investigation with regard to longer term sequelae.

Once it had become well established that infants of very low birthweight and other "at risk" neonates were surviving as a result of modern neonatal care methods, there was considerably less emphasis on the reporting of survival rates and more of a focus on attempting to clarify the still disputed issue of subsequent developmental sequelae (e.g. Kitchen et al., 1980; Vohr & Hack, 1982). Part of the problem in resolving this issue was the dearth of population data on disability (Chalmers & Mutch, 1981).

This research endeavour continued throughout the 1980s with modest progress. The majority of studies were, by now, reporting a levelling off of the prevalence of major handicap at around 8% (e.g. Klein, Hack & Breslau, 1989) but some studies continued to report that low birthweight populations are at considerably greater risk of major neuromotor disorders (Stanley & Alberman, 1984; Michelsson, Lindahl, Parre & Helenius, 1984; Hagberg, Hagberg & Zetterström, 1989). Since the early 1980s, the survival rates of ELBW infants have almost doubled and, if these latter studies are correct, the consequence is the survival of even greater numbers of those children who carry the highest risk of impairment.

2.5.1 Further attempts to clarify the question of major sequelae

To explore the continuing discrepancies in the findings of outcome studies of VLBW children a further large scale review was undertaken in the late 1980s (Hoy, Bill & Sykes, 1988). 24 studies were reviewed spanning the period from the mid 1970s to the mid 1980s. Almost a decade after the earlier reviews of Stewart et al. and Kopp, considerable variation in the reported prevalence of major handicap was still evident. Furthermore, Kopp's warning of the need to consider sample characteristics was still being largely unheeded.

The relatively low rates of major handicap reported in the review studies of the early 1980s, typically 6% to 8% were reflected in a number of later studies (e.g. Alberman, Benson & MacDonald, 1982; Belton, Thistlewhaite, Wilkinson, Maxwell & Elton, 1986; Eilers, Desai, Wilson & Cunningham, 1986; Hack, Caron, Rivers & Fanaroff, 1983; Klein, Hack, Gallagher & Fanaroff, 1985; Wojtulewicz, Alam, Brasher, Whyte, Long, Newman & Perlman, 1993). However, rates of major disability as high as 34%

were reported in other studies (Britton, Fitzhardinge & Ashby, 1981; Eckerman, Sturm & Gross, 1985; Lasky, Tyson, Rosenfeld, Krasinski, Dowling & Grant, 1987).

Importantly, however, those studies that did report upon sample characteristics illustrate how significant such information is and while it is always difficult to draw general conclusions it is all the more so in the absence of such information. The sample investigated by Lasky et al. 1987, for example, was a ventilated group of VLBW infants from impoverished background and rates of major disability as high as 30% were reported. In their discussion, the authors contrast their findings with much lower rates of major disability in other studies where samples are of middle class socioeconomic status. An unexpectedly high rate of major disability of 20% was reported in the study by Britton et al., 1981. Their sample, however, was an ELBW group with birthweights less than 801g who were not born in the neonatal intensive care unit but were transported following birth – often in very poor condition.

Notwithstanding the clear difficulty in drawing general conclusions, there does seem to be a tendency for studies reporting higher rates of major disability to have tested the children earlier in life, typically around two years of age, with developmental checklists or tests. Those studies that follow up the children at three years of age or later, using tests of cognitive ability, generally report lower rates of major disability. It could be, however, that there is some loss to follow up of children who died in the postneonatal period or who were very disabled.

2.5.2 The age-deterioration hypothesis

Some researchers who remained convinced that rates of major sequelae were not levelling off proposed an age-deterioration hypothesis (Holmes, Reich & Pasternak, 1984) whereby a tendency for an increase in intellectual deficits throughout life in the VLBW population was postulated.

The evidence from surveys and reviews of the literature and from major studies does not support the age deterioration hypothesis. Most subsequent research has, by and large, been directed towards discrete developmental domains (e.g. cognitive, neuromotor and scholastic) and more subtle developmental impairment or minor neurological dysfunction, sometimes referred to as neurological "soft signs" (e.g. Hertzig, 1981; Sell, O'Connor, Shafer & Prupis, 1983; Shafer, Shaffer, O'Connor &

Stokman, 1983; Shaffer, Schonfeld, O'Connor, Stokman, Trautman, Shafer & Ng, 1985; Zubrick, Macartney & Stanley, 1988; Powls, 1997.)

2.6 Shift of research focus from major sequelae to lesser morbidities

The shift in the focus of attention of researchers interested in lesser morbidities experienced by VLBW infants, the beginnings of which were noted by Kopp in the mid 1980s, accelerated throughout the late 1980s and early 1990s. Rates of these lesser handicapping conditions were typically reported to be around 10% to 20%. Minor handicap is usually equated to an I.Q. of between 1 SD and 2 SD below the mean (i.e. I.Q. = 70-84). Almost all of the 24 studies in the Hoy et al. review report rates within this range. Again, however, sample characteristics need to be taken into consideration.

The remainder of this review of the literature will be concerned with studies that investigate the outcomes of VLBW children less in terms of survival and major sequelae and more in terms of discrete developmental domains.

Section 2 Cognitive Ability and Scholastic Attainment

2.7 School age cognitive outcomes of VLBW children

2.7.1 The evolution of studies investigating school age outcomes

By the late 1980s a small but increasing number of studies were beginning to report upon VLBW children who had reached school age. From the early days of school age follow up considerable concern was expressed in terms of low scholastic attainments and poor classroom performance (Noble-Jamieson, Lukeman, Silverman & Davies, 1982; Michelsson et al., 1984; Klein et al., 1985; Eilers, et al., 1986; Belton, et al., 1986; Calame, Fawer, Claeys, Arrazola, Ducret & Jaunin, 1986).

Calame et al. (1986) found that school failure occurred more frequently in VLBW children. They found also that the presence of neurodevelopmental abnormality was more common in the VLBW group, especially in those VLBW children who were small for gestational age. (The issue of appropriateness of birthweight for gestational age represents one strand of investigation in this study and is discussed in detail below.) The authors also reported that, where these children had a neurodevelopmental abnormality, school failure appeared to be related to the presence of language disorders. Michelsson et al. (1984) suggested that minor neurological dysfunction is associated with delayed acquisition of language skills which, in turn, has a negative impact on school progress. Klein et al. (1985) highlighted relative weaknesses in visual motor integration and perceptual function as the main factors underlying poor school attainments. This could be interpreted as a higher prevalence of specific learning difficulties/dyslexia in the VLBW group. Children who comprise one subgroup of dyslexics experience difficulties characterised by faulty visual motor integration (e.g. Dobie, 1993). (This issue is developed in detail in Chapter 6.)

By school age, VLBW children are generally reported to have intellectual ability falling within the normal range, but on average 0.5 SD below their heavier birthweight peers (Zubrick et al., 1988; Aylward & Pfeiffer, 1989; Aylward, Pfeiffer, Wright & Verhulst, 1989; Escobar, Littenberg & Petitti, 1991; Ornstein, Ohlsson, Edmonds & Asztalos, 1991; Wolke, 1993; Hall, McLeod, Counsell, Thompson & Mutch, 1995; Botting, Powls, Cooke & Marlow, 1998).

2.7.1.1 General conceptual ability

Most studies report some measure of general conceptual ability such as global IQ scores – although many employ standardised assessment materials that allow for a more detailed investigation of cognitive subskills. It is possible, therefore, to some extent, to compare the results of intellectual assessment between studies. VLBW children are more likely to experience significant developmental delay and learning difficulties (e.g. Aylward, et al.,1989; Wolke, 1991; Hall, et al., 1995; Wolke, 1998; Botting, et al., 1998). Some studies have reported differences between verbal/auditory and visual/performance I.Q. scores (Klein et al., 1985; Vohr & Garcia Coll, 1985; Breslau, Klein & Allen, 1988; Ornstein et al., 1991; Botting, et al., 1998) but other studies have not found such differences (Li, Sauvre, Creighton, 1990; Hall, et al., 1995). This again raises the issue of the possibility that VLBW children are more likely to experience specific learning difficulties. However, a related issue that has not been adequately addressed in the literature concerns the nature of the visual performance tasks in cognitive assessment batteries. Generally speaking verbal/auditory items require no more than a verbal response. Non verbal and spatial items, on the other hand, often require a response that has a fine motor component. It is possible, therefore, that poor performance on non verbal and spatial items by VLBW children has more to do with poor motor competence than poor visual processing. (This issue represents another strand of investigation in this study and is reported in Chapter 5 and discussed in Chapter 6.)

A further level of analysis involves considering a profile of specific areas of cognitive functioning. It may be that patterns of cognitive strengths and weaknesses emerge that explain scholastic performance or that have predictive value for later school outcome. It has been noted that unless global IQ scores are either very high or very low they tend to be poor predictors of later educational attainments (Reid Lyon, 1989; Siegel, 1989; Evans, 1990; Fletcher, 1992; O'Callaghan, Burns, Gray, Harvey, Mohay, Rogers & Tudehope, 1996).

2.8 Hospital centre based studies versus population based studies

The methodological case for population based studies over hospital centre based studies in terms of the investigation of the longer term outcomes of VLBW children has been made time and again over the last three decades (the reader is referred to a discussion of this issue in Chapter 3). It is only by employing a population based study design that selection bias can be avoided in the inception cohort. The problem of, for example, referral patterns that can be associated with a certain hospital can be avoided in population bases studies.

2.8.1 Contributions to the literature from hospital centre and unit studies

While the case for population based studies over hospital centre or unit based studies is well established on methodological grounds, the fact remains that all study groups operate under a range of constraints. Time is a factor for many study groups as group members will often be involved in full time clinical practice. Creating time to trace and subsequently assess children, code and analyse data and report findings presents a considerable challenge. Financial constraints are always operating, and carrying out studies in the centres or units where the study infants and children are being treated makes eminent sense. It also makes the tracing of children for follow up study an easier task as records will be held centrally – although it will always be the case that some children will move away from the area.

Despite the difficulties such as bias in the pattern of referrals, many hospital and centre studies of the last two decades have taken great care over study design and carried out well controlled studies which have made a valuable contribution to the literature. Indeed, if the literature were restricted to population based studies it would be limited to a relatively small number of studies rather than the vast knowledge base that it is. This part of the review of the literature will also include those studies which, while based on geographically defined populations, have small numbers in their cohorts and are centred around single or a small number of hospitals (e.g. Lloyd, Wheldall & Perks, 1988).

This review of the literature will not reiterate methodological shortcomings for each study mentioned if the flaws arise from the fact that it is hospital based. This issue is dealt with in detail in Chapter 3 and the reader is referred, in particular, to the section on "referral bias" for an account of these methodological issues.

2.8.1.1 The Nottingham Study

The Nottingham Study (Abel Smith & Knight Jones, 1990) followed up 43 children born in Nottingham in 1981 and referred to the neonatal intensive care unit at Nottingham City Hospital. The Nottingham Study is one of the earliest controlled studies of the cognitive development of VLBW children in the UK. Prior to the Nottingham study there had, in fact, been 10 previous controlled studies of VLBW children using psychometric measures (Robinson & Robinson, 1965; Harper, Fischer & Rider, 1959; Wright, Blough, Chamberlain, Ernest, Halstead, Meier, Moore, Naunton & Newell, 1972; Kitchen, Ryan, Rickards, McDougall, Billson, Keir & Naylor, 1980; Noble-Jamieson et al., 1982; Drillien, Thompson & Burgoyne, 1980; Michelsson et al., 1984; Klein et al., 1985; Lloyd et al., 1988; Fritsch, Winkler, Flaneyek & Muller, 1986).

The aim of the Nottingham study was to follow up VLBW children (less than 1501g) who appeared to be developing normally (on the basis of earlier assessments) at early primary school age (five years of age) and to compare their cognitive abilities with matched classroom peers.

The authors were following up the notion of "hidden handicap" (Zubrick et al., 1988), that is, concern that if the criterion for normality is simply the absence of major neurological impairment, then minor disabilities leading to a higher incidence of learning difficulties and lower cognitive ability will remain concealed.

The measure of cognitive ability employed in the study was the McCarthy Scales. This test comprises six scales one of which is General Cognitive Index (GCI). The results demonstrated that, when compared to their heavier birthweight classroom controls, the index children performed significantly less well on all six scales, most notably on GCI.

The authors note that none of the comparison children scored below 74 (Mean=100, SD=15) whereas eight of the index children scored below 70. The cut off for special educational provision is usually taken to be IQ less than 70, all of these VLBW children were, however, being educated in mainstream schools and none was in receipt of special help. (The issue of the provision of adequate support for learning is developed in Chapter 6.)

The authors of the Nottingham study drew the conclusion that their study does nothing to alleviate the anxieties over quality of survival – an issue that was coming to the fore by the mid 1980s (Mitchell, 1985).

2.8.1.2 The Finnish Study

The Finnish study (Michelsson et al., 1984) reported similar findings and noted that significantly more VLBW children were in receipt of speech and language therapy. The Finnish cohort comprised 116 VLBW children (less than 1501g) and the comparison group comprised 39 classroom controls. Both the index and comparison children were born in the Institute of Midwifery, Helsinki between 1971 and 1974. The measures of cognitive functioning included the Wechsler Intelligence Scale for Children (WISC) and the Illinois Test of Psycholinguistic Abilities (ITPA). The index group scored significantly lower on the WISC (full scale IQ, verbal IQ and performance IQ). The index group also gained significantly lower scores on almost all scales of the ITPA – the exceptions being auditory sequential memory, manual expression and sound blending. This is an interesting pattern of intact skills as sound blending is clearly auditory and sequential in nature and the fact that short term auditory sequential memory is also intact makes sense – as this would represent the cognitive prerequisite for successful sound blending skills.

2.8.1.3 The Wolverhampton Study

A further controlled study from the same era employing psychometric measures (British Ability Scales) was the Wolverhampton study (Lloyd et al., 1988). Although it was a geographically defined controlled study the numbers of children in the index and control groups was relatively small (45 matched case control pairs – although one index child was reported to be untestable). The authors reported differences in both general IQ between the two groups and differences on the cognitive subscales. The mean IQ for the index group was 93.1 (SD 15) and for the comparison group it was 100.4 (SD 12.9) – a statistically significant difference. While the index children scored lower on all of the BAS subscales presented (eight ability scales and one attainment scale) the differences on only two of the scales was statistically significant (Recall of Digits and Word Reading). Recall of Digits is a test of short term auditory sequential memory, difficulty in this area of cognitive functioning was the only significant difference found in the small controlled study by Fritsch et al. (1986).

The findings of both Lloyd et al. and Fritsch et al. are at odds with findings of most other studies including Michelsson et al. (1984) who found ability in serial digit recall to be intact in their index group and Klein et al. (1989) who reported that visual skills were weaker than the auditory skills in their cohort. A more recent hospital based study employing, like Lloyd et al., the BAS (Jongmans, Mercuri, Dubowitz, Henderson, 1998) found that prematurely born index children achieved lower general IQ scores than their term counterparts. The index children also scored lower on all subscales of the BAS with the exception of short term auditory sequential memory, as measured by Recall of Digits. It is not clear why the results of Lloyd et al. and Fritsch et al. are at odds with those of most other studies, but it is the case that they are two studies with particularly small index groups.

The authors of the Wolverhampton study obtained ratings on the children's overall school performance via a teacher questionnaire. Also obtained were ratings on five school activities. Significantly more index children were rated as performing below average or poorly and a particularly large difference was found in mathematics where 33 (73%) of the VLBW children were performing poorly or below average compared with 12 (27%) of comparison children. It is not clear, however, that the teachers were blind to the birthweight status of the children – possibly introducing an expectation bias affecting the validity of the results of this part of the study.

Lloyd et al. reported, additionally, that children from higher social class groups (determined by the occupation of the father) tended to have higher IQs than those from lower social class groups. Within every social class grouping there was a difference of at least 6.5 points between the VLBW children and their matched controls. These differences, however, were not statistically significant. The differences were, in fact, smaller than differences between children of similar birth weights from different social class backgrounds.

Social background has frequently been reported to be a strong predictor of impaired performance (e.g. Drillien et al., 1980; Eilers et al., 1986). It has also been suggested that the influence of social class background on the performance of VLBW children increases as they grow older (McBurney & Eaves, 1986). However, social class background is not always found to influence the performance of VLBW children. The

Nottingham study, for example, found no independent or interactive effects of social class on the performance of the index children. However, given that it is a hospital based study it is possible that referral patterns were operating that created a social class bias in the cohort.

2.8.1.4 The Liverpool Maternity Hospital Study

An exhaustive study based upon a cohort of VLBW (less than 1251g) children, all of whom were treated at Liverpool Maternity Hospital Special Care Baby Unit, is well represented in the literature. Unlike many other follow up studies, this is a serial follow up study, the study cohort having been assessed at the pre school, primary school and, recently, the secondary school stage.

The Liverpool Maternity Hospital study is of particular interest in relation to the present study as, although it is not a population based study, there are many similarities. The inception cohort was established at approximately the same time as that of the present study (two and a half years prior) and, therefore, the methods of medical intervention in the perinatal period will have been similar. The matched classroom controls were selected according to the same criteria as in the present study and by the headteachers of the mainstream schools. (While a number of other study groups have also employed the selection criteria for the control children used by the Liverpool Maternity Hospital group, there in nothing in the reports from these studies to suggest that this is anything more than coincidental.) The areas of development investigated were, by and large, the same as was the nature of the demographic information collected. Major differences include the fact that assessors in the Liverpool Maternity Hospital Study have not been “blind” to the case status of the children and they have not consistently used the same assessment materials throughout the various phases of their study.

2.8.1.4.1 The six year follow up study

The cohort comprised 76 children born between January 1980 and July 1981 who weighed less than 1251g at birth (Marlow, Roberts & Cooke, 1989). Of these 53 were assessed at six years of age. (Those not assessed had either died, had major impairments and were being educated in the special education sector or, as in the case of three children, parental consent was not forthcoming.) Comparison children, matched for gender, age and classroom environment were selected by the headteachers of the mainstream schools. Cognitive ability was assessed using the Wechsler Pre School and Primary Scales of Intelligence (WPPSI). (Motor skills were also investigated and this aspect of the six year follow up is discussed below.)

Sample characteristics were reported. The age distribution of the two samples was well matched and there were reported to be no significant differences between the index and control groups in terms of socioeconomic status.

The results of the cognitive component of the assessment protocol demonstrated that the index group had, on average, significantly lower IQ scores than their heavier birthweight classroom controls. An eight point difference in median scores was reported between the index and comparison groups.

The WPPSI comprises 10 subscales, five contributing to the verbal scales and allowing for the computation of the verbal quotient and five contributing to the performance scales and allowing for the computation of the performance quotient. The intelligence quotient is derived from the verbal and performance quotients.

The index children performed significantly less well than the comparison group on two of the five verbal subscales and significantly less well on three of the five performance subscales. The prediction made by Marlow et al., that there would be a significant discrepancy between verbal and performance scores, was not borne out. This prediction had been made on the assumption that the index group would be experiencing higher rates of motor impairment and, therefore, a discrepancy between verbal and performance scores might be expected. As it turned out, the index group were found to have an overall reduction in scores compared with the comparison group but with no differential between verbal and visual performance. Although the prediction made by Marlow et al. was not borne out it is an important issue that should be investigated in all studies employing cognitive assessment batteries that place a demand on the motor skills of the children. As mentioned above this is a strand of investigation in the present study although it is one that is rarely addressed in other studies.

2.8.1.4.2 The eight year follow up study

At eight years of age criteria for study sample membership remained unchanged (Marlow, Roberts & Cooke, 1993). Two of the study sample assessed previously at age six years of age were, however, no longer available. Again a matched control group was employed. For 44 of the 51 index children the comparison child was the same as at the six year follow up. For the remaining index children new comparison children were recruited, thus, each index child still had a school matched control.

A test of cognitive ability was not employed at this follow up but the assessment protocol comprised a much broader range of tests of scholastic attainment than had been administered in the previous phase of the study. Areas investigated included reading, spelling, mathematics and handwriting. (Motor skills were also investigated and again this aspect of the eight year follow up is discussed below.)

The index children were found to perform less well than their classroom controls over the entire range of educational tests. Marlow et al. defined satisfactory performance as scores above the 10th percentile for the comparison group. Three times as many index children as comparison children performed poorly on tests of reading, number and spelling. Twenty four (48%) of index children were found to be experiencing difficulty in one or more areas of the curriculum compared with 11 (19%) of comparison children. Nine (18%) index children had difficulties in two curricular areas and six (12%) had difficulties across the breadth of the curriculum.

Marlow et al. concluded that, even with IQ scores falling in the normal range, VLBW children are likely to underachieve at school.

The Liverpool Maternity Hospital Study is one of only two longitudinal studies that has followed its cohort through to the teenage years and undertaken direct assessment of the children during their secondary education (Botting, 1997; Botting et al., 1998) – the other being the Ontario Study (Saigal, Hoult, Streiner, Stoskopf & Rosenbaum, 2000).

2.8.1.4.3 The 12 year follow up study

In the 12 year follow up a cohort of 138 VLBW children comprising two previously studied cohorts was created (Botting et al., 1998). The first group was that of the 53 children of birthweights less than 1251g described above (n=48 at the 12 year follow up) the second group consisted of 93 children of birthweights less than 1501g and gestational age less than 31 weeks (n=90 at 12 year follow up) (Ellis, 1992). The total sample size at this phase of the study was therefore 138 children.

As infants they had all been treated in the Mersey Regional Neonatal Intensive Care Unit of Liverpool Maternity Hospital – the original group between 1980 and mid-1981 and the additional group between January, 1982 and November, 1983. The authors were able to trace and follow up only 80% of the eligible cohort, nevertheless, by combining the two groups they did create a considerably larger cohort than if the study had been restricted to the original study sample of Marlow et al., 1989.

The authors reported that the VLBW children performed less well than the comparison children across the entire range of cognitive (WISC) and educational measures. Mean IQ for the VLBW group was 89.7 (SD 17.2) and for the comparison group mean IQ was 97.8 (SD 17.4). It is noteworthy that the distribution of IQ for the comparison group differs at least to some extent to the normative population distribution. This reinforces the importance of including matched control groups in such studies. Despite this Botting et al. did not derive concurrent norms from their control group with which to compare the index children. The distribution of IQ for both the index and comparison groups is reported in terms of IQ groupings based on published test norms for the WISC. A more accurate picture of the prevalence of serious cognitive impairment might have been achieved by reporting the proportion of index children falling more than 2 SD below the mean for the comparison group. Instead Botting reports on the proportion of index children with IQ scores less than 70 (17 of 121 (12%)) and the proportion of comparison children with IQ scores less than 70 (12 of 163 (7%)). This is an issue that has been raised in the literature (e.g. Bill, Sykes & Hoy, 1986; Wolke, Ratschinski, Ohrt & Riegel, 1994). The decision not to base the IQ distribution for the index group on norms derived from the comparison group was not due to prohibitively small numbers, as the comparison group comprised 163 children. In the present study a major strand of investigation relates to the importance of deriving concurrent norms from the comparison group in order to report accurately rates of poor cognitive ability and scholastic attainment in the index group.

The authors reported that when IQ scores were broken down into their respective verbal and performance components the difference in full scale IQ was mainly due to poorer performance IQ scores. This is in line with the six year follow up report from the Liverpool Maternity Hospital group (Marlow et al., 1989). It is a finding that reemphasises the importance of considering the motor competence of the VLBW children when reporting cognitive ability scores where the assessment activities place a demand upon motor skills.

In terms of educational attainments a further finding of interest in the study of Botting et al. is that some measures of educational attainment (reading comprehension and mathematics) remained significantly different after controlling for IQ. The differences in attainment cannot, therefore, be accounted for solely in terms of differences in intelligence between the index and comparison groups.

The attempt of the authors to identify clear predictors of poor educational outcome at 12 years of age did not meet with a high degree of success. This is common in VLBW studies (e.g. Papile, Munsick-Bruno & Schaefer, 1983; Smedler, Fexelius, Bremme & Lagerström, 1992; Marlow et al., 1993; Roth, Baudin, McCormick, Edwards, Townsend, Stewart & Reynolds, 1993). It was found that IQ at six years is the best predictor of IQ at 12 years. However, the authors acknowledge that to deploy resources to provide additional educational intervention based upon low IQ scores at six years of age is likely to prove inefficient. It was found that motor functioning at six years and head circumference at 12 years are predictive of level of cognitive functioning. Additionally, taking the number of days for which an infant is ventilated as a proxy for the duration of neonatal illness, an association was found with cognitive functioning. In relation to this finding, however, the authors reported marked individual differences within this group whereby some children had little impairment and others experienced considerable deficits.

2.8.1.5 Assessment of increasingly discrete measures of cognitive functioning and scholastic attainment

2.8.1.5.1 Assessment of executive function

A recent hospital based study carried out in Brisbane, Australia (Harvey, O'Callaghan & Mohay, 1998) set out to investigate specific aspects of cognitive functioning. The authors noted that a number of reports had begun to appear in the literature suggesting deficits in executive functioning in VLBW and ELBW children (Lah, Michie, Starte, Gibson, Bowen & Ma, 1994; Willatts, Hall, Forsyth, Nelson & Taylor, 1994). The hypothesis of Harvey et al. was that deficits in executive functioning are responsible for the increased likelihood of ELBW children to experience learning difficulties in comparison to their heavier birthweight peers.

A range of definitions of executive function exists, for example, "a human trait that is critical to attention, memory and learning" (Reid Lyon & Krasnegor, 1996, p.233) and the term executive function has been used synonymously with prefrontal cortex function. Harvey et al. note that executive function has been defined more specifically as behaviour involving planning, inhibition, and the holding of information "on-line" to achieve future goals (Pennington & Ozonoff, 1996). To assess executive function Harvey et al. employed the frequently used Tower of Hanoi task, a finger sequencing task (to test fine motor planning and sequencing) and a tapping test (which assesses the child's ability to suppress imitation and inhibit interfering responses).

The principal finding of the Harvey et al. study was that ELBW group demonstrated significant deficits in executive function when compared with the control group, and this was the case even for those ELBW children who scored within the normal range on the Peabody Picture Vocabulary Test – Revised (PPVT-R.). The PPVT-R (Dunn, 1991) is a standardised test of receptive language and correlates well with other tests of vocabulary and general ability assessment batteries for young children such as the Kaufman Brief Intelligence Test for Children (Childers, 1994).

Harvey et al. reported that the index children performed significantly less well than the control group on the Tower of Hanoi, the finger sequencing task and the McCarthy Scales. The Tower of Hanoi results support those of Lah et al., 1994 (a very small scale study with a sample size of only 15 children) and of Willatts et al., 1994 who assessed 86 LBW children (less than 2000g) who were neurodevelopmentally normal. A comparison of the performance of the Harvey et al. and the Willatts et al. index groups is compromised, however, by birthweight differences (less than 1000g in the former as opposed to less than 2000g in the latter).

While the correlation between tests of executive function and measures of general intelligence are weak, there are stronger associations between executive function and specific aspects of cognitive performance. A link between inhibition and working memory has been put forward (Denkla, 1996) and this may explain a strong correlation between the Tapping Test and the memory subscale of the McCarthy test battery that was found in the Harvey et al. study.

While the performance of VLBW children in discrete areas of cognitive functioning is of obvious clinical interest a drawback of the study by Harvey et al., 1998 is that they are unable to say with any certainty whether deficits in executive function are isolated or are a subset of a broader pattern of cognitive impairments in ELBW children – as there were a number of aspects of cognitive functioning that they did not investigate.

2.8.1.6 Assessment of cognitive functioning in the present study

The issue of the selection of cognitive assessment instruments in the present study is outlined below – following the review of population based studies. In brief, however, the selection of the British Ability Scales in the present study allows for both the generation of a global IQ score and for an investigation of more discrete areas of cognitive functioning. This allows the findings from the present study to be discussed in relation to studies that report global figures of cognitive functioning such as IQ or DQ scores and it also enables an investigation of issues that require an assessment of discrete areas of cognitive functioning.

2.8.2 Contributions to the literature from population based studies

While there is a plethora of follow up studies of VLBW children since the advent of neonatal intensive care, as reference to the bibliography of this thesis will attest, there are only a small number of population based cohort studies that have investigated the outcomes of relatively large groups of VLBW children to school age (e.g. Pharoah, Stevenson, Cooke & Stevenson, 1994a and 1994b; McCormick, Gortmaker & Sobol, 1990; Saigal, Szatmari, Rosenbaum, Campbell & King, 1991; Saigal, Hoult, Streiner, Stoskopf & Rosenbaum, 2000; Veen, Ens-Dokum, Schreuder, Verloove-Vanhorick, Brand & Ruys, 1991; Hille, Den Ouden, Bauer, Van Der Oudenrijn & Verloove-Vanhorick, 1994; Scottish Low Birthweight Study Group, 1992; Hall, et al., 1995;

Whitfield, Grunau & Holsti, 1997; Horwood, Mogridge & Darlow, 1998; Wolke & Meyer, 1999).

Of these studies only the present study and two others are true national cohort studies; the Dutch national cohort study of surviving preterm and VLBW children born in 1983 – also known as the POPs study (e.g.Veen et al., 1991); and the New Zealand national cohort study of surviving VLBW children born in 1986 (Horwood et al., 1998).

2.8.2.1 The Canadian regional cohort (Ontario) study

The New Zealand study (Horwood et al., 1998) and the Scottish Low Birthweight Study (Hall et al., 1995) share much in common with the Canadian regional cohort study of ELBW children born between 1977 and 1981 (e.g. Saigal, Szatmari et al., 1991; Saigal, Rosenbaum et al., 1991; Saigal et al., 2000). The Canadian study followed up 143 surviving ELBW children at 8 years of age and compared their functioning across a wide range of cognitive, educational and other measures with a group of heavier birthweight matched control children. The ELBW cohort was reported to be operating more poorly across all measures of functioning as compared with the control group.

The report on the most recent follow up of the Canadian regional cohort study (Saigal et al., 2000) indicates that the differences in cognitive ability (WISC-R) and scholastic attainments (Wide Range Achievement Test – Revised (WRAT-R)) persist into the teenage years. The age range of the index children at this follow up was 12-16 years of age. Attrition rates were relatively modest with 89% of the index children and 86% of the comparison children being traced and assessed.

The conclusion drawn by Saigal et al. is that there is stability in psychometric measures between eight years of age and the teenage years. They suggest that differences of 13 to 18 points on psychometric measures in the index teenagers compared with their term controls is both statistically significant and clinically relevant. (The issue of statistical significance versus clinical relevance is important in this field of research and it is developed further in Chapter 6 of this thesis.) In brief, population based studies tend to be dealing with large numbers of children. As a result, small differences between the index and comparison groups can be statistically significant. It is not possible to conclude, however, that these statistically significant differences are clinically relevant. However, when differences of 10 IQ points or more are being reported, as is the case with Saigal et al., the authors would seem justified in arguing that this represents a clinically relevant discrepancy. Indeed, a difference of 5 IQ points across a population represents a doubling of the proportion falling more than 2 SD below the mean. Thus, apparently small differences between mean scores can obscure marked differences in the distribution of scores.

On a rather more controversial note the authors also conclude that the demand placed upon special educational resources by ELBW teenagers has economic implications and that the incremental cost of being extremely premature needs to be determined.

2.8.2.2 The New Zealand Study

The New Zealand study group reported upon 298 surviving ELBW children from a birth cohort of 413 born in 1986 (Horwood et al., 1998). The surviving children were traced at 7 to 8 years of age and were assessed on measures of behaviour, cognitive ability, educational attainments and requirement for special educational arrangements. As with the Canadian study, the New Zealand study reported higher rates of behavioural problems and poorer levels of cognitive and academic functioning across all measures as compared to the control group. An additional level of statistical analysis controlled for variability in social, family and other characteristics of the two samples. It was reported that even after controlling for these factors the differences remained.

2.8.2.2.1 Methodological issues relating to the New Zealand study

A weakness of the New Zealand study relates to the selection of the comparison cohort which does not comprise matched controls. For the purpose of comparison Horwood et al. gained access to the Christchurch Health and Development Study (CHDS) cohort. This cohort comprised 1265 children born in Christchurch, New Zealand in 1977. The cohort was studied at birth, at four months, at one year and annually thereafter up to 16 years of age.

The CHDS cohort is, therefore, an urban cohort of children born nine years prior to the VLBW cohort. How representative CHDS cohort is of the New Zealand children born nine years later is questionable. The use of historical controls raises the possibility that differences between the cohorts may be artefacts of changes that have occurred across time in, for example, social conditions between 1977 and 1986 or in measurement processes. The authors put forward a rather unconvincing argument that the differences between the two groups are unlikely to be artefactual as the data collection processes used in the CHDS study and in the VLBW study were supervised by the same researcher using identical measurement instruments administered in, to all intents and purposes, the same circumstances.

The fact remains that it is only the present study that is a true national cohort study with a comparison group matched for gender, age and classroom environment. The most recent follow up of the Dutch study seeks to identify perinatal risk factors and predictors at five years of age of school performance at nine years of age. The Dutch study has, however, tended to use parental and teacher questionnaires rather than direct assessment of children in more recent follow ups.

2.8.2.3 Project on Preterm and Small for Gestational Age infants (POPS) in the Netherlands

The Project on Preterm and Small for Gestational Age infants comprises all surviving pre term (<32 weeks) and/or VLBW infants born in the Netherlands in 1983 (n=1338 liveborn infants).

2.8.2.3.1 The five year follow up

At the five year review a 94% follow up rate was achieved (Veen et al., 1991). The authors reported that, at five years of age, 28% of the children were either handicapped or disabled. At this follow up it was too early for the authors report in detail upon the provision of extra help in class or retention at stage (being kept back a year). It was reported, however, that 12% of the very pre term/VLBW children were in receipt of special education – this compares with a rate of just over 1% in the general population of Dutch five year olds.

2.8.2.3.2 The nine year follow up

The nine year follow up of the Project on Preterm and Small for gestational age infants allowed for a more thoroughgoing investigation of school performance in these children (Hille et al., 1994).

At this phase of the study a slightly lower follow up rate of 88% was reported. By now 19% of the study children were in special education – compared with 6.5% in the general population of Dutch nine year olds. Those children who had not been in special education at five years of age but were by nine years of age were reported to have moderate cognitive impairments and moderate behavioural and learning difficulties. Those children who had been in special education at five years of age were more likely to have had neurodevelopmental or sensory handicap. Of those children who entered special education between five and nine years of age more than half of them were judged as not disabled at five – although most of these children had been assessed as having a degree of neurodevelopmental impairment that could have been considered predictive of learning problems later on.

Of those study children in mainstream educational provision at nine years of age, 32% were reported to be working below their age level (retained at stage) – compared with 10% in the general population. Of those in the appropriate class for their age, 27% were in receipt of additional support and, for those who had been retained, 60% were receiving extra help.

Social class was found to be significantly associated with special education, as was gender with boys faring worse than girls. (The issue of gender and developmental sequelae is discussed in more detail below.) When children with disabilities were left out of the regression analysis – a model which included perinatal and five year variables – it was reported that the most predictive factors for special education were developmental delay, speech and language function, inattention and hyperactivity scores and school results from five years of age. Increased risks of any school failure, not just the provision of special education, in children without disability included mild or severe developmental delay, and marginal or poor school performance at five years of age.

On the basis of their findings the authors conclude that long term follow up of pre term VLBW children is essential – with special attention to the predictors at five years of age.

2.8.2.3.3 Documenting the characteristics of those who drop out

The issue of achieving a 100% follow up or, where this proves impractical, documenting the characteristics of those who have dropped out has been discussed in the literature (Wariyar & Richmond, 1989; Wolke, Sohne, Ohrt & Riegel, 1995). While Wariyar & Richmond argue for the importance of achieving a 100% follow up Wolke et al. acknowledge that this is rarely achieved in prospective longitudinal studies of VLBW/preterm children. Both sets of authors agree that it is those infants with serious developmental delay or impairment and whose mothers are of low educational attainment that are most likely to drop out of such studies. To fail to take into account those infants who have dropped out is to risk an under reporting of poor outcomes in those born preterm or VLBW.

2.8.2.3.3.1 Characteristics of those who dropped out in the Netherlands study

Unlike the majority of studies, Hille et al., 1994 did report upon the characteristics of those who dropped out from the Netherlands study. The authors reported that non response was significantly associated with neurodevelopmental handicap at five years of age and with low socioeconomic status and they acknowledge that this may have led to an underestimation of learning problems.

2.8.2.3.4 Methodological issues relating to the Netherlands study

The Project on Preterm and Small for gestational age infants study does not employ a matched control group. It is, however, a national cohort study therefore the absence of a matched control group represents less of a methodological flaw than would be the case in a study of small sample size. In other words published national norms do represent an appropriate, if not ideal, comparison for a national cohort study. This, of course, assumes that the published norms are current – whether or not this is so is not made clear in the reports from the Netherlands group.

A more serious methodological failing of the nine year follow up was the absence of any direct assessment of the study children – although this is not made clear in the report from this phase of the study. Information was gathered by issuing questionnaires to parents and teachers and additional recorded information on school performance was made available to the authors. Clearly parents are not blind to the birthweight and gestational age status of their offspring. As there is no comparison group in the Netherlands study it is also the case that teachers will not have been blind to the birth status of the children. This introduces the possibility of bias arising from the possible expectations of parents and teachers on the long term outcomes of small and immature infants.

2.8.2.4 The Mersey Region Study

The Mersey Region study has reported periodically upon a geographically defined cohort of low birthweight infants (less than 2001g) born in 1980 and 1981. (Powell, Pharoah & Cooke, 1986; Pharoah et al., 1994a and 1994b).

2.8.2.4.1 The pre school follow up

The Mersey Region study is a prospective, controlled, population based study that set out to undertake psychometric assessment of low birthweight infants. The first report from this study group (Powell et al., 1986) appeared when the children comprising the cohort were still in their pre school years. The report was concerned mainly with survival and morbidity in terms of major sequelae. The children were too young to participate in a standard cognitive assessment battery such as the WISC-R or BAS (although an early years assessment could have been presented e.g. WPPSI), neither could their early attainments in reading and number be assessed.

2.8.2.4.2 The eight year follow up

The eight year follow up of the Mersey Region study (Pharoah et al., 1994a) entailed a more comprehensive assessment of the index cohort and matched controls. As in the case of the Liverpool Maternity Hospital study and the present study, the matched controls were of the same gender, attending the same school and nearest in date of birth to the index child.

The authors of the eight year follow up argue that one of the main strengths of their study is that it is population based and, therefore, less susceptible to bias associated with differential patterns of referral to hospital unlike many other studies (e.g. Botting et al.,1998; Halsey, Collin & Anderson, 1996; Kitchen et al., 1980; Vohr, Garcia Coll, Flanagan & Oh, 1985) especially in relation to social variables such as socioeconomic status and parental income. They also note that theirs is a study employing matched controls unlike other studies (e.g. Saigal et al., 1991; The Scottish Low Birthweight Study Group, 1992b; Gross, Slagle, Eugenio & Mettelman, 1992) and that it is not hampered by being limited to a high risk group (e.g. Zubrick, et al., 1988).

A number of other population based studies employing appropriately matched controls had begun to report upon school age outcomes of VLBW children by the time of the eight year follow up of the Mersey Region study (e.g. Rantakillio & von Wendt, 1985; Lloyd et al.,1988; Abel Smith & Knight Jones,1990). This allowed for a more thoroughgoing comparison of cognitive ability and school attainment across studies than had previously been possible. Of further assistance in this regard was the decision of the Mersey Region group to lower the their birthweight criterion for cohort membership from less than 2001g to less than 1501g in line with other studies – strictly speaking the criterion should have been revised to less than 1500g in accordance with WHO definitions. (The Mersey Region group did continue to include a sample from the heavier birthweight group in the eight year follow up study.)

2.8.2.4.2.1 Cognitive ability and reading attainment at eight years of age

The main outcome measures at the eight year follow up were IQ score (WISC-R), reading age (Neale Analysis of Reading Ability – Revised) and the Test of Motor Impairment (TOMI). (Motor and neurological outcomes are discussed below.)

With regard to the IQ scores on the WISC-R, the mean IQ difference between index and comparison children was 8 to 10 points. The difference between the index and control boys scores was slightly greater than for the girls. A gradient effect by birthweight was also found, whereby index children less than 1001g scored less well than those between 1001-1500g who, in turn, scored less well than the sample of children from the 1501-2000g group. The small gender difference applied across all birthweight groupings.

The Neale Analysis of Reading Ability can be used to gain scores for reading accuracy, reading comprehension and rate of reading. The eight year follow up of the Mersey Region study reported formally on only the reading comprehension scores. The reading comprehension ages of the index children were found, on average, to be six months below those of the comparison group. The authors report, informally, that the findings for reading accuracy and rate of reading were similar.

2.8.2.5 Assessment of cognitive functioning as a profile of skills (The Bavarian Study)

A recent study has set out to identify more reliable indicators of later school performance (Wolke & Meyer, 1999). The authors carried out a prospective, controlled, population based study in Bavaria (an established long term follow up study of very preterm infants; n=264). The principal hypothesis, at the six year follow up, was that very preterm children have a range of cognitive problems as opposed to specific developmental deficits.

Rather than using a traditional instrument for assessing cognitive ability such as the generally favoured Wechsler Intelligence Scale for Children-Revised, Wolke and Meyer selected the Kaufman Assessment Battery for Children (K-ABC) (Kaufman, Kaufman, 1983). The K-ABC is similar to the British Ability Scales (BAS) (Elliott, Murray, Pearson, 1983) in that it is based on neuropsychological and information processing theories of cognitive functioning. Intelligence is measured using the Mental Processing Composite which comprises eight scales, each designed to test a discrete area of fundamental cognitive functioning. Like the BAS it also includes three scales to test the acquisition of basic scholastic skills.

In addition to administering the K-ABC, Wolke and Meyer also presented tests of expressive and receptive language, and prereading skills. They found that on all measures of cognitive ability, language development and prereading skills the index group gained significantly lower scores than the comparison group. Interestingly, and contrary to some of the studies cited above, the authors found that the effect of being very preterm at birth has greater implications for cognitive development than socioeconomic factors.

There were two other main findings of the Wolke and Meyer study. Firstly, for the very preterm children, problems seldom occurred in isolation. Much more frequently than their full term peers, very preterm children were found to have multiple cognitive problems. Secondly, the index group were found to have pronounced deficits in tasks such as visual spatial recognition, logical reasoning and pattern building and memory. In other words, very preterm children were found to have difficulty in tasks that required the processing of simultaneous information. This form of information processing deficit was found to be 31 times greater in the index group than in the control group. It was so pronounced, indeed, that when it was controlled for, most of the differences in achievement and language abilities between the index and control groups disappeared. As predicted, Wolke and Meyer found specific developmental deficits to be rare. They found such deficits only for speech articulation, quality of speech and numeracy.

The Bavarian Study (Wolke and Meyer, 1999) and the study by Harvey et al., 1998 described above reflect a tendency in LBW research to move away from an approach characterised by the reporting of global measures of intelligence. Both these studies, especially that of Wolke and Meyer, point towards the likelihood of a range of cognitive weaknesses in very preterm and VLBW children as compared with their full term and heavier birthweight peers. Both studies, however, are reporting on children still in their early years. Further investigation of these cohorts is necessary to examine the development of specific areas of cognitive functioning and executive function and the relationship between deficits in these areas in pre school and early school years and later educational attainments. Further follow up research will help establish if the findings reported in these studies represent development delays or more permanent deficits.

2.8.2.6 Assessment of cognitive functioning in the present study

In the present study the British Ability Scales (BAS) was administered to the index and comparison groups. The BAS was selected partly as a result of the concern expressed by researchers such as Wolke that global measure of intelligence may obscure information relating to the spectrum of cognitive subskills and, moreover, that the typical finding of IQ falling in the region 0.5 SD below the mean may offer insufficient warning (partly because of the use of outmoded test norms in some studies) about the difficulties VLBW children might experience in their school years – particularly with the increasing demands of later school years.

The BAS, like the Kaufman-ABC, is an assessment battery comprising a range of tests designed to investigate specific areas of cognitive functioning. Just as other studies have selected the Kaufman-ABC as their assessment instrument (e.g. Li, et al 1990; Teplin, Burchinal, Johnson-Martin, Humphry & Kraybill, 1991; Achenbach, Howell, Aoki & Rauh, 1993; Weisglas-Kuperus, Baerts & Sauer, 1993) so too the BAS is increasingly being adopted as the assessment battery of choice to assess the cognitive subskills of VLBW children (e.g. Lloyd et al., 1988; Jongmans et al., 1998).

The BAS, and the recent revision the BAS II, can be used to generate visual and verbal IQs and a global IQ where this is appropriate. This is most often of benefit when a comparison is to be made with studies reporting global measures of intelligence such as IQ or DQ such as would be derived from the Stanford Binet or Bayley Scales or verbal/auditory and visual/performance IQs as would commonly be reported in studies using the WISC-R (e.g. Botting et al. 1998; Horwood et al., 1998).

A further area of investigation that can be undertaken by employing an assessment instrument that is designed to assess performance in discrete areas of cognitive functioning is that of specific learning difficulties/dyslexia. Children who experience specific learning difficulties generally underachieve in the areas of literacy, and sometimes numeracy, in relation to their level of general conceptual ability. It is important, however, to look for a cognitive basis for this underachievement as, for example, extensive absence from school or lack of motivation could also lead to this outcome. There are patterns of cognitive strength and weakness that are associated with specific learning difficulties. The two most common patterns are characterised by (i) a relative weakness in short term auditory memory and (ii) a relative weakness in visual perception (e.g. Dobie, 1993). Assessment batteries such as the BAS and the K-ABC are appropriate instruments for the investigation of such specific areas of weakness. If the position of those studies that report VLBW children to be experiencing specific learning difficulties is to be upheld it is necessary that they demonstrate specific areas of cognitive functioning to be significantly weaker than the level of general conceptual ability. The issue of specific learning difficulties/dyslexia occurring in VLBW populations represents one strand of investigation in this thesis.

2.8.3 Scope for comparison of the findings of the Scottish Low Birthweight Study with those of other population based studies of VLBW children

A principal strand of investigation in the present study is to compare the cognitive and scholastic outcomes of a national cohort of VLBW children at eight to nine years of age with a group of heavier birthweight matched control children. The population based studies reviewed immediately above are the most methodologically similar to the present study and it will be of particular interest to discuss the results of the present study in relation to the findings of these studies (Chapter 6). However, none of these studies is methodologically identical and moreover there are bound to be social and cultural difference between the study cohorts. Therefore any differences in findings must be treated with caution.

The present study is the only one to have carried out a follow up on a complete national cohort of VLBW children at school age where a comparison group matched on gender, age and classroom environment has been included. The Mersey Region study (Pharoah et al., 1994a) is very similar methodologically but it is not based on a complete national cohort. The New Zealand study is also very similar methodologically but while it is based on a complete national cohort, historical controls are used. The Netherlands study does not employ any form of comparison group and the nine year follow up did not involve direct assessment of the children.

Of the two studies that did carry out direct assessments of their study cohorts none used the same cognitive assessment instrument as employed in the present study – although all three studies used materials that allow general, verbal and visual IQ scores to be computed. The selection of the British Ability Scales in the present study does set it apart from the majority of other studies, but it is a strength in that it allows for a more detailed investigation of cognitive functioning which, as discussed above, allows for an exploration of issues such as the occurrence of specific learning difficulties/dyslexia and other patterns of cognitive strengths and weaknesses.

2.9 First set of hypotheses (cognitive ability and scholastic attainment):

There is an ever increasing body of research evidence that suggests that VLBW children are at increased risk of longer term morbidity and functional impairment in middle childhood. The previous phase the Scottish Low Birthweight Study (the four year follow up) found that the LBW children (less than 1750g) scored lower than the test norms on scores of cognitive functioning, but not significantly so. A major shortcoming of this phase of the Scottish Low Birthweight Study was the absence of a comparison group. It is possible that the use of test norms, already 10 years or more out of date, resulted in an overestimation of the level of cognitive functioning in the cohort. The presence of a control group in this phase of the study means that this methodological flaw has been eliminated. (The issue of employing comparison groups and using these comparison groups to generate concurrent norms is investigated in Chapter 5 and discussed in Chapter 6.)

The four year follow up of the Scottish Low Birthweight Study demonstrated that the study population did not differ from test standards in the proportion of children functioning <10th percentile in the subscales of Naming Vocabulary and Recall of Digits. A relative sparing of short term auditory memory has been reported in other hospital based controlled studies (e.g. Jongmans et al., 1998, Michelsson et al., 1984.) and population based controlled studies (e.g. Whitfield et al., 1997).

A significantly higher proportion of the study population scored below the 10th percentile on Visual Recognition, Verbal Comprehension and Number Skills.

Only one ability subscale of the BAS that forms a part of the four year protocol also forms a part of the protocol for eight year olds, namely, Recall of Digits – testing short term auditory sequential memory. One test of scholastic attainment also comprises a part of both the four year and eight year assessment protocols, namely, Number Skills. (However, the actual assessment activities differ.)

Although the subscales administered at four years and eight years differ, the areas of cognitive functioning assessed by the scales are the same. Therefore, Visual Recognition (four year protocol) assesses short term visual memory, this is assessed at eight years by Recall of Designs. Similarly, Verbal Comprehension (four year protocol) and Word Definitions (eight year protocol) are both tapping into retrieval and application of knowledge from long term memory. These subscales, of course, while attempting to tap into discrete areas of cognitive functioning, are not identical and, therefore, are not measuring exactly the same skill. It is only Recall of Digits that is identical at four and eight years.

Based on the findings of the four year phase of the Scottish Low Birthweight Study, taking into consideration the methodological flaws discussed above, and the findings of other controlled studies of the cognitive ability and scholastic attainments of VLBW children in middle childhood, the following hypotheses are made:

i. The mean composite general IQ, verbal IQ and visual IQ scores of the index group will be lower than those of the comparison group. It is also predicted that the distribution of IQ will be both shifted downwards and skewed downwards for the index group relative to the comparison group.

ii. A higher proportion of index children will be identified as having serious cognitive impairment (more than 2SD below the mean) when concurrent norms derived from the comparison group are used as opposed to published test norms.

iii. The index group will gain lower mean T scores than their heavier birthweight matched controls on all the subscales of the British Ability Scales. (A corollary of this prediction is that no evidence of specific cognitive impairment will be found.)

iv. Any difference between the index and comparison groups on the Recall of Digit subscale will be less pronounced than on the other subscales of the BAS.

v. Where a child's IQ score is not more than 1SD below the mean but where motor functioning is below the 10th percentile, performance on visual items of the BAS (including composite Visual IQ) will be poorer than performance on verbal items (including composite Verbal IQ).

vi. Children in the index group will gain lower scores, on average, on measures of scholastic attainment (Word Reading and Basic Number Skills) than children in the comparison group.

vii. A higher proportion of index children will be identified as experiencing serious difficulties in reading and number (more than 2SD below the mean) when concurrent norms derived from the comparison group are used as opposed to published test norms.

Section 3 Neuromotor Functioning

2.10 The prevalence of major neuromotor disorders in VLBW populations

Many studies have reported the increased prevalence of major neuromotor disorders in populations of VLBW and low gestational age children (e.g. Kitchen et al., 1980; Kiely & Paneth, 1981; Hack et al., 1983; Michelsson et al., 1984; Klein, Hack & Breslau, 1989; Hagberg et al., 1989; Elliman, Bryan, Elliman, Walker & Harvey, 1991). It has been reported that, by eight years of age, some children who apparently "outgrew" the neuromotor signs of cerebral palsy present at earlier ages, had poor cognitive ability (Nelson & Ellenberg, 1982). Other researchers suggest that those children who continue to have subclinical neuromotor deficits, as manifested by neurological signs in the absence of obvious motor disability, may go on to exhibit cognitive deficits later on (Amiel Tison & Stewart, 1989).

In the literature review that follows particular attention is given to those longitudinal studies that help to explore the issue of developmental delay versus deficit. In other words, the question to which there is as yet no clear answer is what proportion of the neuromotor deficit seen in VLBW, very preterm infants will improve with maturation and how much is associated with persistent neurological deficit.

2.11 School age neuromotor outcomes of VLBW children

While all of the population based VLBW studies have investigated cognitive and educational sequelae of low birthweight not all have considered the motor competence of VLBW children (e.g. Saigal et al., 2000; Wolke & Meyer, 1999). To give adequate coverage to the literature on neuromotor competence it is, again, necessary to review hospital centre based studies. A number of hospital based studies provide detailed investigations of motor functioning and/or neurological status in VLBW samples (e.g. Escobar et al., 1991, Jongmans, Henderson, de Vries, Dubowitz, 1993; Powls et al., 1995; Powls, 1997; Jongmans et al., 1998).

2.11.1 Contributions to the literature from hospital centre and unit studies

Studies from the early 1990s onwards have tended to report less on the prevalence of major physical disability such as cerebral palsy and to concentrate on a more detailed level of neuromotor competence, especially, gross motor movement, fine motor control and balance.

Despite the fact that many studies investigating the neuromotor competence of VLBW and preterm children have demonstrated problems in this area of development (e.g. Marlow et al., 1989; Scottish Low Birthweight Study Group, 1992, Jongmans et al., 1993; Powls et al., 1995), there is still a great deal that is not known. While the studies cited above did employ standardised tests of motor functioning, the majority do not. There has been a tendency to select motor tasks from unstandardised broad based neurodevelopmental screening tests. Poor performance on such tasks has then been used to classify children as clumsy or dyspraxic. This has tended to mean that functional motor tasks such as skipping have not been separated out from, for example, the measurement of reflexes. The studies described below differ in that they have all adopted at least one standardised test of motor competence. This has generally been the Movement Assessment Battery for Children (Movement ABC), (Henderson & Sugden, 1992). (This test was formerly known as the Test of Motor Impairment and often referred to as the "TOMI" (Stott, Moyes & Henderson, 1984).)

2.11.1.1 The Finnish Study

One controlled study of motor functioning in VLBW (less than 1501g) children from the 1980s was the Finnish study – described above in relation to cognitive development (Michelsson et al., 1984). The TOMI was used to compare motor functioning in index and comparison groups. The authors reported that significant differences were found between the index and comparison groups with the index children displaying poorer motor functioning. The authors noted the similarity in the findings of their study and those reported in the studies of the same era (e.g. Noble Jamieson et al., 1982 and Drillien et al., 1980). The authors reported that scores on the TOMI correlated significantly with both scores of school achievement and IQ. The conclusion reached by Michelsson et al. was that an organic lesion that causes motor disturbance must also be responsible for the dysfunction in learning and behaviour.

While there are certainly many studies that report problems in both the cognitive/educational and neuromotor domains of development this does not constitute support for the assumption of Michelsson et al., 1984 that there is an organic lesion that is responsible for both motor impairment and problems in learning and behaviour. Indeed, it does seem a strong assumption to make. It fails to capture the idea that VLBW children do not constitute a homogenous group. It runs contrary to the assertion of Sommerfelt's, cited at the start of this chapter, that LBW may have many aetiologies and that the relationship of the problems associated with LBW are still not clearly understood.

The assumption of Michelsson et al. can, however, be tested by setting up the hypothesis that motor or neurological impairment can occur in the absence of cognitive or school difficulties. That is, to investigate if incontrovertible neuromotor difficulties ever occur in isolation in VLBW children. (Specific hypotheses are presented below.)

One of the first studies of the 1990s to investigate motor functioning in VLBW children at school age (Escobar et al., 1991) found that there was an increase over time in the numbers of children with more subtle neuromotor difficulties. This was a particular cause for concern as the school age follow up of this study demonstrated that problems of motor functioning that had first been identified in the early years, and that had often appeared relatively minor, were still present and having an impact on school performance and, in later years, on everyday life. Other study groups have made similar observations (e.g. den Ouden, 1991; Ellison & Foster, 1992).

2.11.1.2 The Liverpool Maternity Hospital Study

This longitudinal study, described in detail above in relation to cognitive and scholastic development, has also investigated the neuromotor competence of VLBW children. (Marlow et al, 1989; Marlow et al., 1993; Powls et al., 1995; Powls, 1997.)

2.11.1.2.1 The six year follow up study

The motor skills component of the assessment protocol in the six year follow up comprised the Test of Motor Impairment (TOMI) and a formal neurological examination. The Henderson revision of the TOMI (Stott, Moyes, Henderson, 1984) – later superseded by the Movement Assessment Battery for Children (Henderson, Sugden, 1992) – comprised eight items subdivided into three groups of skills, namely, ball skills (two items), manual dexterity (three items) and dynamic balance (three items). A standard neurological examination and Touwen's Examination of the Child with Minor Neurological Dysfunction (Touwen, 1979) – an assessment for minor neurological signs were additional components of the neuromotor assessment protocol. The minor neurological signs included dysdiadochokinesia; finger following, circling, opposition and placing; the finger nose test; dyskinetic movements and associated hand movements during heel walking.

At six years of age the index children were found to be significantly more impaired than their matched controls on the TOMI – performing significantly less well on seven of the eight subtests than the comparison children.

With regard to the neurological aspect of the assessment at six years of age, neurological signs were more common and more pronounced in the index children. This applied, in particular, to dysdiadochokinesia, dystonic movements and associated hand movements when heel walking – where such signs were found to occur significantly more frequently than in the comparison group.

2.11.1.2.2 The eight year follow up study

At the eight year follow up (Marlow, et al., 1993) the motor skills component of the assessment battery once again comprised the TOMI but, on this occasion, a standard neurological examination was not undertaken.

The motor functioning results at eight years were similar to those reported at six years. The index children had higher overall TOMI scores – indicating poorer motor performance. The index children performed less well across the entire range of individual items with the single exception of jumping over the cord – an activity that contributes to the dynamic balance composite.

While the case control analysis demonstrated statistically significant differences at eight years in terms of motor functioning, the authors also reported falls in the impairment scores between six and eight years. This observation applied to both the index and control groups but was more marked in the index group. The conclusion drawn by the authors was that the index children had caught up some of the motor impairment reported at the six year follow up.

Taking into consideration the educational aspects of the eight year follow up the authors reported that motor assessment at six years was the best predictor of school problems at eight years. A motor impairment score of five or more correctly identified 15 of 16 (94%) of children who were experiencing school problems in two or more areas.

2.11.1.2.3 The 12 to 13 year follow up study

The principal aim of the 12 to 13 year follow up (Powls et al., 1995), as far as motor functioning was concerned, was to determine whether the motor impairments identified at the earlier follow up studies persisted or if the improvements noted at the eight year follow up were maintained.

Forty seven of the original cohort of 53 were traced and assessed using the Movement Assessment Battery for Children (Movement ABC). Forty of the original classroom controls were traced and 20 new classroom control children were recruited.

The authors reported that the improvements in motor functioning observed at eight years of age were maintained but that there were no further improvements. Clinically significant or borderline impairment was observed in 51% of the index children. Sixteen of the 47 (34%) index children had significant impairments as compared with three of the 60 (5%) comparison children. It was also reported that girls had significantly higher overall impairment scores than the boys and higher scores on a wider variety of subtests than the boys.

The most significant differences between the index children and their classroom controls were observed in the three manual dexterity sub tests. This is an important finding, as this is one of only two comprehensive studies reporting upon the outcomes of VLBW children at the secondary school stage (Powls et al., 1995; Saigal et al., 2000). Problems with motor functioning have implications for fully functional participation in a mainstream school curriculum (e.g. Zubrick et al., 1988). This will be at least equally true or even more the case for participation in a regular secondary school curriculum. In other words, educational difficulties are likely to increase as the demands on, for example, written language skills increase throughout the secondary school years.

2.11.1.3 The Hammersmith Hospital Study

A comprehensive study of perceptual motor functioning of children born prematurely between January, 1984 and February, 1986 in the Hammersmith Hospital, London is well represented in the literature (e.g. Jongmans et al., 1993; Jongmans et al., 1997; Jongmans et al., 1998).

The focus of the study very much concerns perceptual motor functioning. The authors' use of the term "perceptual motor" functioning appears to be synonymous with neuromotor functioning – a term used more widely by other study groups. Certainly the assessment instruments used by Jongmans et al. are largely the same as those employed by other study groups, especially the Movement ABC. They do, however, include a test of visual motor integration (Beery, 1982) which is rarely included in the assessment protocols of other studies.

While other domains of development such as cognitive ability, scholastic attainment are considered it is perhaps not surprising that motor functioning is of central interest – as the senior member of the group is Sheila Henderson who was responsible for the Henderson revision of the Test of Motor Impairment and its successor the Movement Assessment Battery for Children.

The criteria for inclusion in the study were (i) gestational age of less than 35 weeks; (ii) a minimum of three cranial ultrasound scans 24 hours apart from each other; (iii) no congenital abnormalities; and (iv) a minimum of one examination in the follow up clinic between 40 weeks postmenstrual age and two years of age. Of 219 survivors who met the inclusion criteria 190 were traced at six years of age. Parental consent was forthcoming in all cases but seven were excluded either because of known medical conditions or because of the presence of clinical signs that were suggestive of conditions that might interfere with normal development. The comparison groups for neurological functioning and perceptual motor competence comprised two groups of 66 and 88 children, respectively, matched for age, gender and racial distribution of the group.

Neurological functioning was assessed using Touwen's Examination of the Child with Minor Neurological Dysfunction (Touwen, 1979). The Movement ABC and the Developmental Test of Visual Motor Integration (Beery, 1982) were used to assess perceptual motor competence.

The authors reported that the index group performed significantly less well than the matched comparison group on almost all measures. The differences on the Movement ABC and Touwens's test of neurological functioning were substantial – despite the exclusion of 26 children who had cerebral palsy. The prevalence of neuromotor problems in their index group was high (48%). That is, 48% of the index group failed at least one of two standardised test of neuromotor competence that were administered.

2.11.1.3.1 Possible bias in the Hammersmith Hospital Study

It seems likely that there is a referral bias affecting the Hammersmith Hospital Study. Although children with cerebral palsy were excluded from the study the Neonatal Intensive Care Unit of the Hammersmith Hospital tends to admit a high proportion of particularly poorly infants.

Notwithstanding the concerns regarding possible referral bias, the findings regarding motor competence in the Hammersmith Hospital Study are similar to those reported in other studies that employed the Movement ABC (e.g. Levene, Dowling, Graham, Fogelman, Glaton, & Philips, 1992; Michelsson & Lindahl, 1993; Powls et al., 1995). The referral bias, however, probably explains the substantial differences reported by the Hammersmith group between index children and their controls which are larger than the case control differences reported by other study groups.

The Liverpool Maternity Hospital Study (Powls et al., 1995) study is described in detail above. Levene et al., 1993 reported on a VLBW group at five years of age. They found that the index children performed significantly less well on all three composites of the TOMI. The Finnish study (Michelsson & Lindahl, 1993) reported on motor functioning in their cohort at nine years of age. They found that 34% of the index group scored more than 1 SD below the mean for the comparison group and 16% scored more than 2 SDs below the mean. The literature would appear to include only one study where mean scores on neuromotor functioning (TOMI) fall within the normal range (Roth et al., 1993). This study, however, reported only group mean scores on the TOMI. Without information being provided on the proportion of children whose scores fell outside of the normal range it is difficult to compare the findings of this study with those of other studies.

2.11.1.4 Difficulties in comparing the findings of studies that have employed the TOMI or Movement ABC

Comparing studies that have used the TOMI or Movement ABC is complicated by the fact that different cut offs have been adopted to signify impaired motor functioning. The Hammersmith Study (e.g. Jongmans et al., 1998) adopted a cut off of below the 15th percentile for the comparison group whereas the Scottish Low Birthweight Study (Scottish Low Birthweight Study Group, 1992a) adopted a more stringent cut off of below the 10th percentile. The authors of the Hammersmith study report that 44% of children performed below the 15th percentile and 19% below the 5th percentile on the Movement ABC. Had the authors of this study reported data on the proportion of children falling below the 10th percentile it would have enabled a comparison with earlier reports from the Scottish Low Birthweight Study (Scottish Low Birthweight Study Group, 1992a; Mutch, et al., 1993) that 20% of the Scottish VLBW cohort fell below the 10th percentile.

It is important that the prevalence of problems of neuromotor functioning be followed up in the longer term. The Liverpool Maternity Hospital study has reported some catch up in motor impairment between six and eight years of age but no further improvements thereafter. The Scottish Low Birthweight Study has data on the motor competence of a complete national cohort of VLBW children from four and a half years of age onwards and is well placed to contribute to literature on the longer term motor outcomes of these children.

2.11.2 Contributions to the literature from population based studies

Only one of the population based studies discussed above in relation to cognitive ability and scholastic attainment reports in any detail on neuromotor functioning, namely, the Mersey Region Study (Powell et al., 1986; Pharoah et al., 1994a).

2.11.2.1 The Mersey Region Study – the eight year follow up

The Mersey Region study, as described above, has reported periodically upon a geographically defined cohort of low birthweight infants (less than 2001g) born in 1980 and 1981 (e.g. Pharoah et al., 1994a). At the eight year follow up the TOMI was employed to assess motor competence. For a comparison of motor functioning the case-control pairs were subdivided into three groupings: less than 1001g, 1001-1500g and 1501-2000g.

The authors reported that the lowest birthweight group had the highest TOMI scores (most impaired) and they also show the greatest difference when compared with their matched controls.

The total sample comprised 232 matched pairs, 27 (11.6%) of the index children had scores indicative of definite motor impairment and 49 (21.1%) had scores indicative of moderate motor problems. Two of the comparison children (0.9%) had definite motor problems and 21 (9.1%) had moderate motor problems.

The authors also reported the results of motor competence categorised by gender and these are discussed below.

2.11.2.2 The British Columbia Study – the nine year follow up

The British Columbia Study (Whitfield et al., 1997) was mentioned briefly above in relation to the cognitive development. This study is one of the few to report extensively on both the cognitive and motor outcomes of a population based cohort of VLBW children.

Whitfield et al. followed up 90 ELBW children (less than or equal to 800g) born in the province of British Columbia between 1974 and 1985 – representing a 91% follow up rate. Comparison children were matched for race, gender and age.

The authors reported upon fine and gross motor skills using the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978). The index children performed significantly less well than the comparison children on the tests of both gross and fine motor functioning. The difference between the two groups was greatest for fine motor functioning.

Whitfield et al. also investigated gender differences in motor functioning and the relationship between motor competence and cognitive ability/scholastic attainment. These aspects of their study are discussed below.

A methodological weakness of the British Columbia Study is the timescale over which children were enrolled in the study. Enrolment began in January, 1974 and ended in June 1985. There are a number of problems associated with this timescale. First of all, considerable advances in neonatal care techniques occurred between the mid 1970s and the mid 1980s. Therefore, the perinatal experiences of the index children will have changed over the 11 year period. Secondly, other changes may have occurred across time in, for example, social conditions between 1974 and 1985. Thirdly, difficulties arise in establishing an appropriate comparison group. Whitfield et al. did this in two phases. The first group of control children were recruited from an elementary school in a lower to middle class catchment area when the index survivors born between 1974 and 1982 reached school age – these children were matched for race, gender and age. A second group of 40 comparison children were recruited between 1983 and 1984 at three years of age from community centres and health units in districts of similar social class distribution to the index children. The authors decided to excluded 10 of the comparison children who were of higher social class and retained those who most closely matched the index children on indices of socioeconomic status.

The authors did not report whether there were changes across time in the prevalence of motor impairment. They did, however, present a detailed account of the sociodemographic and perinatal variables in relation to both the index and comparison groups and reported no significant differences as far as the sociodemographic characteristics are concerned.

2.12 The relationship between neuromotor competence and cognitive ability and educational attainment

Mostly for reasons of organisation and accessibility to the reader this chapter has considered cognitive ability/scholastic attainment and neuromotor functioning under separate sections. Also of interest, especially within the context of identifying and meeting educational needs, is the question of the relationship between problems in neuromotor functioning and contemporaneous problems in other developmental domains, particularly cognitive ability and attainments in literacy and numeracy.

2.12.1 Do perceptual motor problems ever occur in isolation?

As discussed above, many studies have reported that problems of neuromotor functioning are very common in VLBW children (e.g. Mutch et al., 1993; Marlow et al., 1993; Michelsson & Lindahl, 1993; Jongmans et al., 1998). These studies are, however, examples of the few that have considered the possible relationship between problems of neuromotor functioning and problems in other domains of development. Most studies report the prevalence of problems in different developmental domains such as cognitive, language, neuromotor, scholastic, social/emotional separately. Occasionally a study may present a correlation matrix (e.g. Ellison, 1983).

Two of the aforementioned studies have used statistical techniques to explore relationships between motor functioning and cognitive/educational functioning (Mutch et al., 1993; Marlow et al., 1993). The first of these studies (Mutch et al., 1993) used a cluster analysis technique to identify groups of children demonstrating distinct patterns of strength and weakness in terms of cognitive and motor functioning. Marlow et al., 1993 using a discriminant function analysis technique were able to demonstrate that difficulty in neuromotor functioning at the pre school stage is predictive of poor scholastic attainments at eight years of age. It has been very rare for a study to explore the question as to whether problems of neuromotor functioning ever occur in isolation or if they are always accompanied by problems in other areas of development. The Hammersmith Hospital Study appears to be the only one that has investigated this issue (Jongmans et al., 1998).

The most recent study by the Hammersmith Hospital group discussed above (Jongmans et al., 1998) set out to investigate not only differences between prematurely born children and comparison children on tests of neurological functioning and perceptual motor competence but also to examine (i) whether perceptual motor difficulties in prematurely born children ever occur in isolation and (ii) to examine the relationship between extent of perceptual motor difficulties and associated problems in other domains of development.

With regard to the first question the authors reported that of the 75 children who failed both tests of perceptual motor functioning, 15 performed satisfactorily on all other measures. Interestingly, nine of these 15 children had shown signs of brain damage in the neonatal period (as detected by ultrasound scans) the other six had presented no signs of brain abnormality.

2.12.2 The relationship between the extent of perceptual motor difficulties and contemporaneous problems in other developmental domains

To investigate the relationship between the extent of perceptual motor difficulties and presence or absence of difficulties in other areas of development, Jongmans et al., 1998 created three sub groups of children – those who failed both tests of perceptual motor functioning, those who failed only one and those who passed both. The authors reported a positive relationship between the extent of a child's perceptual motor difficulties and the occurrence of difficulties in other developmental domains. For example, children who failed both tests obtained the lowest IQ scores and had the least well developed reading skills. It was also reported that those children who failed both tests were of lower gestational age than those who passed one or both tests.

The British Columbia Study (Whitfield et al., 1997) reported that 32% of the index children with no cognitive or learning disability had a problem in at least one fine motor area.

The present study provides the opportunity to investigate the occurrence of motor difficulties in the absence of problems in other developmental domains in a population based cohort of VLBW infants with a comparison group of matched classroom peers. Michelsson et al. 1984 propose that an organic lesion is responsible for both problems of neuromotor functioning and learning difficulties. The existence of neurological and/or motor problems in the absence of cognitive or learning difficulties would cast doubt on this hypothesis.

The present study also provides an opportunity to investigate the relationship between motor competence, neurological functioning and cognitive ability/scholastic attainment. The assessment instrument of neurological functioning, namely, the Quick Neurological Screening Test (Mutti, Sterling and Spalding, 1978) is of particular interest as it purports to identify children with a neurological basis for their learning difficulties. The Quick Neurological Screening Test (QNST), including its use within the context of this study, is described in greater detail in Chapter 4.

2.13 Second set of hypotheses (motor competence and neurological functioning):

As is the case for the cognitive and scholastic domains of development the body of research evidence that suggests that VLBW children are at increased risk of longer term morbidity and functional impairment in middle childhood continues to grow.

The previous phase the Scottish Low Birthweight Study (the four year follow up) found that the LBW children (less than 1750g) performed significantly less well on the Test of Motor Impairment than the population on whom the test was standardised. This was so even when those with known neuromotor disability or visual impairment were excluded from the analysis. Of those children who were less than 1000g at birth 40% were considered to be impaired compared with 20% of the 1000-1499g children and 16% of the 1500-1749g children. The investigation of a gradient effect across the birthweight groupings – using the χ^2 for trend statistic – was not significant for the overall TOMI score but was significant for three of the eight subtests.

As has been mentioned above a major shortcoming of the previous phase of the Scottish Low Birthweight Study was the absence of a comparison group. The present study – the eight year follow up – allows for a comparison of motor competence and neurological functioning in a complete national cohort of VLBW children with matched classroom peers.

Based on the findings of the four year follow up of the Scottish Low Birthweight Study and the findings from other controlled studies of the motor competence and neurological functioning of VLBW children in middle childhood, the following hypotheses are made:

viii. The proportion of children classified as being motor impaired, as defined as performance below the 10th percentile on the Movement ABC, will be higher in the index group than in the comparison group.

ix. A greater proportion of the index children will be classified as "suspicious" or "abnormal" in terms of their neurological status compared with the comparison group.

x. Index children who fall below the 10th percentile for the comparison group on the Movement ABC and are classified as "suspicious" or "abnormal" in terms of their neurological status (QNST) will perform more poorly on measures of educational attainment than those index children who belong to only one of these groups.

xi. Index children who fall above the 10th percentile for the comparison group on the Movement ABC and are classified as "normal" in terms of their neurological status (QNST) will perform more satisfactorily on measures of educational attainment than those index children who belong to one of these groups.

An additional area of investigation in this study examines whether problems in neuromotor motor functioning ever occur in isolation or if they are always associated with contemporaneous problems in other developmental domains.

Section 4 Additional Areas of Investigation

2.14 Differential effects of birthweight/preterm birth and small for gestational age on survival and postnatal development

A subset of hypotheses in the present study is concerned with the differential effects of very low birthweight and SGA on cognitive development and scholastic attainment. (The specific hypotheses are outlined below.) Many of the early studies reporting upon the adverse effects of SGA were concerned with infants who had experienced growth retardation in late gestation – sometimes extending to full term. These studies suggested that being born small for gestational age is associated with a range of adverse outcomes in developmental domains such as motor competence, cognitive functioning, vision and hearing (e.g. Drillien, 1972; Ounsted & Ounsted, 1973; Francis Williams & Davies, 1974; Fancourt, Campbell, Harvey & Norman, 1976; Neligan, Kolvin, Scott & Garside, 1976; Drillien et al., 1980; Parkinson, Scrivner, Groves, Bunton & Harvey, 1986). There now exists an increasingly extensive literature on the outcomes of children who were VLBW/ELBW or very/extremely premature and who were small for gestational age (e.g. Gutbrod, Wolke, Soehne, Ohrt & Riegel, 2000; Hutton, Pharoah, Cooke & Stevenson, 1997). There is also continuing interest in the outcomes of SGA infants born at full term (e.g. Sommerfelt, Andersson, Sonnander, Ahlsten, Ellertsen, Markestad, Jacobsen, Hoffman, Bakketeig, 2000).

As improvements in neonatal care techniques have brought about improved rates of survival of ELBW and extremely premature infants there has been a tendency for researchers to focus increasingly on infants born close to the limits of viability. Intrauterine growth retardation usually occurs in the third trimester but extremely low birthweight infants are almost always born in the second trimester and extremely premature infants always so. Therefore, studies that are most likely to capture SGA children are those that have a higher birthweight criterion, for example, less than 2500g and those that investigate infants with a lesser degree of prematurity. It is really only in the last decade that sufficient numbers of SGA infants in ELBW and extremely preterm cohorts have survived to enable rigorous studies of this group of infants to be undertaken. It is this that has brought about the gradual increase in the numbers of published studies on the outcomes of VLBW/ELBW or very/extremely premature SGA infants.

2.14.1 Small for gestational age versus appropriate for gestational age within different developmental domains

Surveying the literature it is apparent that studies reporting on the outcomes of VLBW children who were SGA sometimes do so on measures within some domains of development but not others. An example of such a study is the Hammersmith Hospital Study (Jongmans et al., 1997). (The Hammersmith Hospital Study is discussed in detail above in relation to neurological functioning and motor competence.) The study protocol included a cognitive assessment component (British Ability Scales) but differences in cognitive functioning are only reported in terms of comparing the index (preterm) and control groups. The investigation of the effect of being SGA is limited to measures of neurological and motor functioning. The Nottingham study (Abel Smith & Knight Jones, 1990), on the other hand, investigates only cognitive ability and scholastic attainment. The aim of this study, as described above, was to compare VLBW infants with matched classroom controls on measures of cognitive ability. The authors did, however, investigate differences in scores of cognitive ability between SGA and AGA children, but found no such differences.

2.14.2 Early studies of the differential effects of SGA and AGA in VLBW infants

While, intuitively, it may make sense that VLBW infants who have also experienced intrauterine growth retardation should be at greater risk for poor growth and other adverse developmental outcomes, there is no consensus about this in the literature. One early study found that SGA is a better predictor of level of outcome at eight years of age than is gestational age (Neligan et al., 1976). From the same era, some of the few studies that had reported on the longer term outcomes of preterm SGA infants supported these findings (Commey & Fitzhardinge, 1979; Davies, 1981) while others reported a more favourable outcome (Lubchenco & Delivoria-Papadopoulos, 1972; Vohr, Rosenfield & Cowett, 1978). Sample sizes in these early studies tended to be small, particularly so in the Lubchenco & Delivoria-Papadopoulos study. Sometime the degree of intrauterine growth retardation was not reported (Vohr et al., 1978). Most of these early investigations of preterm SGA infants were only short term follow up studies and very few followed the children through to school age (Neligan et al., 1976).

Studies from the 1970s reporting on the school age outcomes of full term SGA children tended to report that while the incidence of neurological impairment was the same for SGA and AGA children, the SGA children had more educational problems warranting special educational services (Fitzhardinge & Steven, 1972; Rubin, Rosenblatt & Balow, 1973). Fitzhardinge & Steven reported that while the IQ scores of the SGA children were within normal limits, speech delay and learning disabilities occurred more frequently in the full term SGA children.

2.14.2.1 Methodological flaws of early studies of the differential effects of SGA and AGA in VLBW infants

It is difficult to draw any general conclusions from these early studies as a result of the differing methodologies employed. Sample sizes were always small, degree of intrauterine growth retardation was not always reported, samples sometimes comprised a mixture of full term and preterm SGA infants and the use of comparison groups was rare.

2.14.3 More recent studies of the differential effects of SGA and AGA on the outcomes of VLBW infants

Even with the passage of time the differential effects of SGA and AGA on the longer term development of VLBW children are still not well established. The findings of Neligan et al., 1976 are, by and large, supported by those of a recent population based study which is discussed below (Hutton, Pharoah, Cooke & Stevenson, 1997). Another recent study has, however, found completely the reverse (Spinollo, Capuzzo, Piazzi, Baltaro, Stronati & Ometto, 1997). Yet other studies have reported not only poorer growth and lower levels of cognitive functioning in SGA children but also a higher incidence of prenatal and perinatal complications (Frisancho, Fields & Smith, 1994; Pryor, Silva & Brooke, 1995; Paz, Gale, Laor & Danon, 1995.

2.14.3.1 Methodological issues relating to more recent studies of SGA and AGA VLBW infants

Methodological issues continue to make it difficult to compare findings. It is still doubtful that more recent studies are investigating the same factors. Study samples still tend to be characterised by a wide range of gestational ages and birthweights in the study samples and the definition of SGA adopted varies from study to study. Thus studies of school age outcomes have tended to differ in their reports of the relative incidence of, for example, intellectual deficits in VLBW/very preterm infants who were SGA compared with those who were AGA (e.g. Calame et al., 1986; Hadders Algra, Huisjes & Towen, 1988).

2.14.3.1.1 Differences in criteria for classifying infants as SGA

A principal methodological difference that may account for much of the disparity in findings relates to the different criteria used for classifying children as SGA. Examples of commonly used criteria include Lubchenco's growth curves which define an SGA infant as less than the 10th percentile of birthweight for gestational age (Lubchenco, Hansmann & Boyd, 1966) and Usher's standards, which use a cutoff of two standard deviations below the mean birthweight (i.e. third percentile) for gestational age (Usher & McLean, 1969).

2.14.3.1.2 Definition of SGA employed in the present study

The present study employed a criterion for SGA based on the Scottish data on 894,066 livebirths born between 1975 and 1989 (Anonymous, 1990). A cut off point of below the 10th percentile was taken to define small for gestational age. Other studies have employed the same criterion (e.g. the Mersey Region Study – Pharoah et al., 1994a) thus allowing for a comparison of findings from the present study and other population based studies from the same era.

2.14.4 Differential effects of preterm birth and small for gestational age on cognitive development – The Mersey Region Study

In the Mersey Region study, of the 232 index children who comprised the cohort, 91 were small for gestational age and 141 appropriate for gestational age. The authors suggest that the apparently high proportion of SGA children arose because the birthweight upper limit of the cohort was 2000g, that is, their total geographically defined cohort of children less than 1501g together with the sample of heavier birthweight index children (1501-2000g). In other words those infants who weighed less than 2000g but were of normal gestational age were preferentially included.

The authors reported that the case control differences were statistically significant for both the cognitive assessment (WISC) and reading comprehension. The differences between the SGA and AGA children on both the measures of cognitive ability and reading comprehension were not, however, significant.

2.14.4.1 SGA as a continuous variable in the Mersey Region Study

The question of differences between SGA and AGA children was revisited by the Mersey group in a report reanalysing the data (Hutton et al., 1997). In this analysis adequacy of fetal growth was determined by birthweight ratio – a technique developed in the early 1990s for identifying intrauterine growth retardation in infants (Sanderson, Wilcox, Johnson, 1994; Wilcox, Johnson, Maynard, Smith, Chilvers, 1993). The individualised birthweight ratio is the ratio of observed birthweight to the expected birthweight for a given gestational age. Using birthweight ratio allowed Hutton et al. to treat SGA as a continuous variable rather than a category of children and to investigate associations between SGA and a variety of outcomes.

Both univariate and multivariate analyses were carried out – the latter as social variables were thought likely to be confounded with both birthweight ratio and cognitive ability. In the univariate analysis (linear regression) birthweight ratio but not gestational age was significantly associated with IQ. Birthweight was found to be associated with performance IQ but not verbal IQ – the association was also present for full scale IQ. There was no significant association between gestational age or gender on any of the IQ scores.

In the multivariate analysis (multiple regression) the association with birthweight ratio persisted after controlling for social variables. The association of birthweight ratio with verbal IQ was similar to that for full scale IQ, although slightly less pronounced. The association of birthweight ratio and performance IQ was stronger.

It was reported that the measure of reading ability showed no appreciable association with either birthweight or gestation and only reading comprehension was found to be associated with birthweight ratio.

The conclusion reached by the authors is that being small for gestational age and preterm birth differ in their effects on cognitive development. Cognitive ability is negatively associated with the degree of intrauterine growth retardation but not with preterm birth.

2.14.5 Issues relating to the criteria for matching comparison children

A further methodological consideration relates to the fact that comparison children have rarely been matched for the birthweight and gestational age grouping of the SGA children. This causes difficulties in terms of separating out the relative effects of SGA and short gestation. This latter shortcoming has been addressed in a collaborative study in Scandinavia. SGA infants from three centres, two centres in Norway and one is Sweden, were enrolled in the study (Sommerfelt et al., 2000). The mean verbal IQ (Norwegian version of the WPPSI-R) was four points lower and the mean non verbal IQ three points lower for children in the SGA group. The authors reported, however, that parental factors were more strongly associated with cognitive functioning than was intrauterine growth retardation. While the Sommerfelt et al. study does match SGA and AGA children for gestational age, the findings cannot be generalised to VLBW infants.

2.14.5.1 AGA comparison children in the Scottish Low Birthweight Study

In the present study the preferred methodology would have been to compare the SGA children with AGA control children matched by birthweight and AGA control children matched by gestational age – a methodology adopted in a number of recent studies (e.g. Sung, Vohr &Oh, 1993; Wallace, & McCarton, 1997; Gutbrod, Wolke, Soehne, Ohrt & Riegel, 2000). This did not prove possible as adopting this methodology would have resulted in prohibitively small numbers of children in certain groups. That is, effects related to birthweight and/or gestational age might have been obscured as a result of small group sizes.

It must be acknowledged, therefore, that this means that there may be a gestational age bias in the Scottish Low Birthweight cohort as far as the investigation of SGA versus AGA is concerned. Those studies that have compared preterm SGA infants with AGA infants of similar birthweight have often reported poorer developmental outcomes for the AGA infants than the SGA infants (e.g. Drillien, 1970; Francis-

Williams & Davies, 1974; Vohr, Rosenfield & Cowett, 1978; Vohr & Oh, 1983; Kitchen et al., 1984; Hack & Fanaroff, 1984). However, these findings are likely to have resulted from the AGA groups being less mature than the SGA groups.

In the present study it proved possible to obtain the SGA/AGA status of 491 of 590 comparison children from the Information and Statistics Division of the Scottish Home and Health Department. This allowed the investigation into the differential effects of SGA and birthweight to be pursued further in the comparison group. While by definition the comparison group have birthweights of 1750g or above, the advantage of investigating this group is that it will not be affected by the gestational age bias that is likely to be operating on the index group.

2.14.5.2 Studies that have matched AGA comparison children by birthweight and by gestational age

Of those studies that have investigated the impact of both birthweight and gestational age on the outcomes of preterm SGA infants, one study has reported that SGA infants demonstrated higher rates of neurological abnormalities in the first year than AGA infants matched for gestational age (e.g. Pena, Teberg, & Finello, 1988). Another study reported lower cognitive scores at one, two and three years (Sung et al., 1993). In both these studies, however, the AGA children matched by birthweight tended to gain similar cognitive scores to the SGA children. Another study from around the same time (Robertson, Etches & Kyle, 1990) reported no differences on measures of cognitive ability and scholastic attainment at eight years of age in their sample of SGA children in comparison with either the AGA group matched by gestational age or the AGA group matched by birthweight. However, Robertson et al. used a different criterion for classifying their children as SGA and their sample sizes were small. These factors may account for the differences in the findings reported in their study and those of Pena et al., 1988 and Sung et al., 1993.

2.14.5.2.1 The Bavarian Study

The differential effects of being SGA, VLBW and premature on cognitive development have been investigated in a more rigorous manner in a recent study by the Bavarian group (Gutbrod et al., 2000). In this study 115 VLBW infant were classified as SGA on the basis of birthweight below the 10th percentile for gestational age. The methodology employed by Sung et al., 1993 was adopted whereby the index group was compared with two groups of AGA infants – one group matched according to birthweight and the other according to gestational age.

Two early reviews (five months and 20 months) looked at growth measures and general development (Griffiths scale of Babies Abilities). The 56 month review investigated, additionally, vocabulary and language comprehension skills and cognitive development (Columbia mental maturity scales).

The AGA group matched by gestational age demonstrated the most satisfactory growth up to the fifth year. This group also achieved significantly higher scores on all developmental and cognitive measures than the other two groups. Few differences were reported between the index group and the AGA group matched by birthweight. The results of developmental assessments were similar at the early reviews although, at the 56 month review, AGA group matched by birthweight achieved lower scores on performance intelligence and language comprehension. It was also reported that when perinatal factors were controlled for only the group differences in growth remained. In other words, as far as cognitive development is concerned, the authors suggest that perinatal factors may have a greater detrimental effect than whether or not VLBW infants are born SGA or AGA.

The results of the Gutbrod et al. study do not concur with the results from the Merseyside study reporting upon the differential effects of preterm birth and birthweight ratio on cognitive development and motor competence, (Hutton, et al, 1997). Hutton et al. reported that birthweight ratio but not short gestation was predictive of cognitive ability at eight years of age whereas the Gutbrod et al. found that short gestation has a greater detrimental effect upon cognitive development than does intrauterine growth retardation. There are, however, clear methodological differences between the two studies. Gutbrod et al. classified children as being SGA on the basis of birthweight below the 10th percentile for gestational age whereas Hutton et al. opted to treat SGA as a continuous variable in the form of birthweight ratio. Those studies that have adopted the methodology of matching AGA comparison children by birthweight and by gestation (e.g. Sung et al., 1993) have broadly reported similar findings – at least as far as cognitive development is concerned.

2.14.6 Small for gestational age versus appropriate for gestational age on tests of neuromotor functioning

Although the Liverpool Maternity Hospital study group has carried out an intensive longitudinal investigation of neuromotor functioning in VLBW children they have not investigated differences between small for gestational age infants and appropriate for gestational age infants (Marlow et al., 1993; Powls et al., 1995). However, the Hammersmith Hospital group (Jongmans et al., 1997) has explored this issue. The study sample and methods are described above, in brief, neurological functioning was assessed using Touwen's Examination of the Child with Minor Neurological Dysfunction. The Movement ABC and the Developmental Test of Visual Motor Integration were used to assess perceptual motor competence. The authors report that children whose birthweight fell below the 10th percentile for their gestational age (n=52) did not differ from children whose birthweight was appropriate for their gestational age (n=119) on any of the measures of neurological functioning or perceptual motor competence. While no differences were found between the SGA and AGA index children there were significant differences between the index and comparison groups on all measures of neuromotor functioning – as described above. It was also mentioned above that there may well be a referral bias affecting the Hammersmith Hospital Study – as the neonatal care unit tends to admit a high proportion of very sick infants. The poor perinatal condition of this cohort may be masking differences in outcome for SGA and AGA infants.

The eight year follow up from the Mersey study (Hutton et al., 1997) – described in detail above in relation to cognitive ability – also included an investigation into the differential effects of SGA and preterm birth on motor development. The overall score for the Test of Motor Impairment (TOMI) was employed as the measure of motor competence. Whereas an association was found between the birthweight ratio, low birthweight and prematurity on measures of cognitive ability and reading comprehension, there was a different pattern of associations for motor competence. The authors reported that they found motor ability to be positively associated with gestational age but negatively associated with the degree of fetal growth retardation.

2.14.6.1 Investigation of the effects of SGA versus AGA on neuromotor functioning in the present study

As mentioned above the preferred methodology in the present study would have been to compare the SGA children with AGA control children matched by birthweight and AGA control children matched by gestational age. This did not prove possible as a result of prohibitively small numbers of children in certain groups.

The investigation of neuromotor functioning is therefore based on a comparison of SGA and AGA index children. Again, as the Scottish Low Birthweight Study cohort is defined by birthweight less than 1500g this means that a gestational age bias may be operating.

The investigation of neuromotor functioning will include an examination of differences between those SGA and AGA comparison children for whom SGA/AGA status was available.

2.15 Gender differences

In terms of relating VLBW research to practice in education and educational psychology, the issue of a possible gender differential in cognitive ability and scholastic outcome in VLBW children is of considerable importance. In recent years a debate has ensued, particularly within education and politics, regarding the poor scholastic attainments of boys in comparison to their female counterparts. That this is so is generally accepted (e.g. Sukhnandan, 1999). Why it should be so and how best to intervene to improve the scholastic performance of boys continue to be subject to debate.

2.15.1 Gender differences in survival and major sequelae

There is no argument that male VLBW infants are at greater risk of perinatal death than female infants (e.g. Stevenson, Verter, Fanaroff, Oh, Ehrenkranz, Shankaran, Donovan, Wright, Lemons, Tyson, Korones, Bauer, Stoll & Papile, 2000). Furthermore, male VLBW survivors are reported to experience major sequelae more often than females (Brothwood, Wolke, Gamsu, Benson & Cooper, 1986; Paneth, Wallenstien, Kiely & Susser, 1982; Khoury, Marks, McCarthy & Zaro, 1985; Yu, V.Y.H., Downe, Astbury & Bajuk, 1986; Hogue, Buehler, Strauss & Smith, 1987;

Jakobovits, Jakobovits & Viski, 1987; Resnick, Carter, Ariet, Bucciarelli, Evans, Furlough, Ausbon & Curran, 1989).

The study by Brothwood et al. (1986) was a hospital based study of VLBW (less than 1500g) born during 1980-1982 and admitted to a London hospital neonatal intensive care unit. The authors reported not only higher mortality in boys than girls but also increased prevalence of post natal complications. Longer term monitoring to two years of age demonstrated a continuing disadvantage for boys in all areas of development - with the exception of motor function. Some of the differences were found to have diminished between one and two years of age but others, in particular, language ability and personal and social skills were found to have increased. The authors also reported that respiratory distress syndrome and pulmonary interstitial emphysema was associated with increased mortality in boys during the first year of life.

The study by Resnick et al. (1989) considered the effects of both gender and race by birthweight groupings on infant mortality – longer term outcomes were not reported. Their sample consisted of 16,183 infants treated in a tertiary neonatal intensive care unit between 1980 and 1987. The authors reported that survival was greater for females in the birthweight range 500-1500g, but that they found no gender difference in survival for the birthweight group 1500-2500g.

The implication to be drawn from the findings of the studies discussed above, and studies that have reported similar findings (Paneth et al., 1982; Khoury et al., 1985; Yu et al., 1986; Hogue et al.,1987; Jakobovits et al., 1987), is that VLBW boys are doubly disadvantaged. Boys in general underperform in relation to girls of the same age, especially in education, and furthermore VLBW boys seem to be disadvantaged in relation to VLBW girls. These hospital centre and relatively small scale studies all report higher rates of neonatal mortality in boys and longer term developmental disadvantage. Additionally, however, they all had study samples defined by birthweight and it has been postulated that a gestational age bias might have been operating (Verloove-Vanhorick, van Zeben-van der Aa, Verwey, Brand & Ruys, 1989).

The issue of a possible gestational age bias has been addressed in an investigation of gender differences in survival and longer term outcome in a population based cohort study in the Netherlands (Verloove-Vanhorick, Veen, Ens Dokkum, Schreuder, Brand & Ruys, 1994).

The Netherlands group, in their nationwide collaborative study, collected perinatal and follow up data on 94% of surviving infants of less than 32 weeks gestation and/or birthweight less than 1500g born in 1983 (Verloove-Vanhorick et al., 1989). Unlike the studies discussed above, boys were not found to be at increased risk of neonatal mortality. Where agreement did exist with the other studies was in terms of developmental sequelae. Boys were found to be at significantly greater risk of handicap than girls.

The Netherlands group reported on gender differences in disability and handicap once again in their five year follow up (Verloove-Vanhorick et al., 1994). Whereas the Netherlands group had previously reported that neonatal mortality was the same for male and female infants, in the five year follow up it was reported that postneonatal death was more frequent in boys than in girls – this was said to be due, in part, to sudden infant death syndrome. As a result total mortality until five years of age was greater in boys than in girls (34% and 31% respectively).

Of those who survived until five years of age there was no gender difference in the rates of disabilities that did not result in handicap. The prevalence of handicap in boys was three times greater than in girls for both major handicap (10% and 3% respectively) and minor handicap (11% and 4% respectively). The inclusion of birthweight and gestational age in a multivariate analysis did not affect the results – either in term of mortality or handicap at five years of age. Neither the inclusion of congenital anomalies nor the inclusion of a range of perinatal factors in yet another multivariate model affected the results. The authors reported, lastly, that gender differences appeared to have increased considerably between two and five years of age.

2.15.2 Gender differences in cognitive ability and scholastic attainment

The Mersey study reported on gender differences in terms of IQ and reading comprehension scores in the eight year follow up (Pharoah et al., 1994a). Employing the WISC-R the mean IQ difference between index and comparison children was 8 to 10 points. The differences between the index and control boys scores were reported to be slightly greater than for index and control girls. This is a little misleading, however as mean IQ scores were higher for index boys than index girls. The mean IQ scores were also higher for control boys than control girls. This applied to all the birthweight groupings (less than 1000g, 1000-1500g and 1501-2500g). It is arguable, therefore, whether this truly represents a male disadvantage.

As far as scholastic attainment is concerned in the Mersey Region Study, the reading scores of index boys were higher than for the index girls in the less than 1000g and 1000-1500g birthweight grouping. It was only in the 1501-2500g birthweight group that index girls scored higher than index boys. It is not clear if any of these differences are statistically significant as the authors only report statistical analyses for cases and controls.

At the very least, then, the Mersey study does not support the findings of the Netherlands groups – although the study population was, on average, three years older than the Dutch cohort at the time of reporting.

Thus, while the findings reported in the Netherlands study at the five year follow up suggest that gender appears to be an important determinant in all of the areas of outcome that were assessed this was not the case in the Mersey study.

The present study provides an opportunity to investigate the issue of gender differences in cognitive ability and scholastic attainment in a total national cohort (the strength of the Netherlands study) with matched comparison group (the strength of the Mersey study).

2.15.3 Gender differences in neuromotor functioning

While the majority of studies that find gender differences in outcome report a male disadvantage, the Liverpool Maternity Hospital Study found the opposite. The authors of the 12 year follow up of this study (Powls et al., 1995) reported that girls had significantly higher overall TOMI scores than the boys and, in addition, they had higher scores on a wider variety of TOMI subtests than the boys – indicating poorer motor performance

A number of population based studies have reported on gender differences in neuromotor functioning. The Mersey Region Study presented the results of the TOMI categorised by birthweight groupings and gender (Pharoah et al., 1994a). In the less than 1000g group one boy (17%) and one girl (8%) had definite motor impairment – however the numbers were very small (six males and 13 females). In the 1001-1500g grouping 10 boys (12%) and eight girls (11%) had definite motor impairment (of 85 males and 71 females) and in the heaviest birthweight grouping (1501-2000g) four boys (18%) and three girls (9%) had definite motor impairment (of 22 males and 35 females). Thus any male disadvantage is very marginal indeed.

The British Columbia Study (Whitfield et al., 1997) reported no gender differences in motor functioning using the Bruininks-Oseretsky Test of Motor Proficiency.

The Netherlands Study (Verloove-Vanhorick et al., 1994) appears to be the one population based study that reports significant differences between male and female index children. The assessment protocol was reported to have included a test of neuromotor function – although the name of the particular test was not provided. The authors reported a significant males disadvantage both in terms of neuromotor functioning and school performance.

One possible explanation for the differences in the reported findings from these studies is the age of the children at the time of assessment. In the Netherlands Study the children were five years of age at the time of this assessment (Verloove-Vanhorick et al., 1994). In the Mersey Region Study (Pharoah et al., 1994a) the average age of the index children was eight years and in the British Columbia Study (Whitfield et al., 1997) the average age was eight years and six months. The Liverpool Maternity Hospital Study group in their longitudinal study reported some catch up between five and eight years of age (Marlow et al., 1993). The authors did not report, however, whether catch up was greater for males than for females. Most other studies that have reported a male disadvantage in male VLBW or very preterm children have reported on their cohort in the early school years (e.g. Lindahl, 1987; Henderson & Hall, 1982; Drillien et al., 1980). The 12 year follow up of the Liverpool Maternity Hospital Study (Powls et al., 1995) as described above reports a female disadvantage. The New Zealand Study (Horwood et a., 1998) also investigated gender in relation to a possible gradient relationship between birthweight and levels of functioning. The average age of the New Zealand cohort at the time of the assessment was seven to eight years of age, that is, somewhere between the mean age of the Netherlands cohort and the mean ages of the Mersey Region and British Columbia cohorts. The New Zealand Study is described in more detail below in relation to a gradient effect by birthweight but, in summary, while some male disadvantage was reported it was more modest than that reported in the Netherlands Study. It may be therefore that gender disadvantage in neuromotor functioning changes over time.

In the present study the average age of the index children is almost exactly that of the Mersey Region cohort and of the British Columbia cohort. Following on from the discussion above gender differences in neuromotor functioning would not be predicted.

2.16 The gradient model of the relationship between birthweight and levels of functioning

This model proposes that there is a pattern of outcome related to birthweight – in that higher risk is associated with lower birthweight. It is argued, therefore, that it should be possible to observe a relationship between birthweight grouping and levels of functioning and the prevalence of problems. The New Zealand study, for example, looked at the pattern of outcome risks in relation to birthweight (Horwood et al. 1998). The authors found that their results fitted the gradient model in that, across almost all measures, ELBW children had lower levels of cognitive and educational functioning and higher rates of behavioural and other problems than VLBW children who, in turn, had lower levels of functioning and higher rates of problems than the comparison sample.

The analysis also took into consideration gender and the gradient relationship appeared to apply equally for boys and girls despite the fact that boys had higher risks of some outcomes than girls. The authors suggest that this finding is reassuring from the point of view of VLBW boys as it indicates that VLBW boys are not at greater relative risk than VLBW girls with regard to overall levels of functioning in middle childhood. While a number of studies have demonstrated a relationship between birthweight grouping and level of functioning in the domain of cognitive functioning this has seldom been the case with neuromotor functioning. This issue represents another strand of investigation in the present study.

2.17 Third set of hypotheses (SGA versus AGA, gender and gradient effect):

The following hypotheses are made:

xii. Those index children who were small for gestational age will perform more poorly on measures of cognitive ability and scholastic attainment than those index children who were of appropriate size for gestational age. It is also hypothesised that comparison children who were SGA will perform more poorly on measures of cognitive ability and scholastic attainment than their AGA comparison counterparts

xiii. Those index children who were small for gestational age will perform more poorly on measures of motor competence and neurological functioning than those index children who were of appropriate size for gestational age. It is also hypothesised that comparison children who were SGA will perform more poorly on measures of motor competence and neurological functioning than their AGA comparison counterparts

xiv. There will be no gender differences on any measures of cognitive functioning or scholastic attainment.

xv. There will be no gender differences on any measures of motor competence or neurological functioning.

xvi. There will be a gradient of risk by birthweight whereby index children less than 1000g will exhibit higher rates of cognitive and scholastic difficulties than the heavier birthweight index children of 1000-1499g who, in turn, will exhibit higher rates of difficulties than the comparison children. It is hypothesised that the gradient effect will apply to IQ distributions and distributions of scholastic attainment.

xvii. There will be a gradient of risk by birthweight whereby the index children less than 1000g will exhibit higher rates of neuromotor difficulties than the heavier birthweight index children of 1000-1499g who, in turn, will exhibit higher rates of difficulties than the comparison children. It is hypothesised that the gradient effect will apply to the proportion of children classified as motor impaired and numbers of children classified as "suspicious" or "abnormal" on the QNST.

The results of the analyses relating to the three sets of hypotheses outlined above are presented in Chapter 5. Some of the more routine analyses are presented in appendices 1 to 10. The reader will be directed to the relevant appendices where appropriate.

Chapter Three

Low Birthweight Research – Methodological Issues

The principal aim of this thesis is to document the cognitive, scholastic and neuromotor outcomes at eight to nine years of age of a total Scottish population of very low birthweight (VLBW) survivors. If the present study is to advance this field of research endeavour it is necessary to consider the hypotheses, methodology, design, analysis and results in relation to other outcome studies of VLBW and very premature infants. It has been pointed out in the preceding chapters that comparing outcome studies of VLBW infants is difficult. There are many reasons why this is so but the chief difficulty relates to the disparate methodologies employed.

This chapter serves to pull together the methodological issues that frequently recur throughout this thesis. That is, those methodological issues that need to be taken into consideration when designing a follow up study of this sort and when attempting to compare findings with those from other studies.

3.1 Outcome is not simply a measure of medical intervention

It is clear that there is a need to evaluate new forms of medical intervention. It would be unethical not to do so and the legacy of the 1950s when there was a dramatic rise in blindness (retinopathy of prematurity) as a result of the administration of concentrated oxygen to low birthweight neonates pays testament to this notion. It is important to bear in mind, however, exactly what is being evaluated – it will rarely, if ever, be the medical intervention alone. Factors such as genetic predisposition, intrauterine environment and events, perinatal treatment and postnatal health and socioeconomic environment until the time of the assessment all need to be considered as aspects of the evaluation.

3.2 Follow-up and serial follow-up studies of VLBW infants

One strand of low birthweight research is concerned with monitoring progress in a range of developmental domains across time. Another strand involves efforts to predict later outcomes from assessments carried out at some earlier stage. The ability to be able to predict developmental and health outcomes would be to the advantage of VLBW infants, in terms of offering appropriate intervention as early as possible. Research which attempts to map out the development of VLBW and other high-risk infants or to use data to predict later outcomes must be longitudinal in nature.

There is a distinction between follow-up studies where outcome is investigated only once and those where the cohort is traced and assessed on a number of occasions. The majority of studies in the literature are "once only" follow up studies and often the follow up investigation is carried out in the pre school years. Those studies which follow up their cohorts on at least two occasions are termed serial follow-up studies. These studies are more likely to follow their cohorts into the school age years and allow the possibility of capturing improvement or deterioration over time.

Follow-up and serial follow-up studies both require appreciable effort in terms of the gathering of large amounts of data in an objective and reliable manner. In the case of serial follow-up studies the investigation may span many years or even decades.

3.3 Methodological issues of importance in follow-up studies

3.3.1. Minimising attrition rates

One of the most important goals for researchers conducting serial follow-up studies is to encourage compliance on the part of the participants. Achieving an 80% follow up rate presents little difficulty; it is the tracing and gaining compliance of the remaining 20% or so that proves so difficult. Keeping attrition rates low is particularly important as reviewers of the literature have reported that non participants can differ systematically from those who agree to participate (e.g. Kiely & Paneth, 1981; Wolke, Sohne, Ohrt & Riegel, 1995). Parents of children with developmental problems may view participation in the study as an opportunity for additional professional attention and advice. On the other hand parents of healthy infants may find it hard to see how any advantage can accrue from allowing their child to be enrolled in such a study. This difficulty is illustrated in a study in which the incidence of spastic dyplegia was reported to be 32% among VLBW children (Lubchenco et al., 1972). However, only those children who returned to the medical centre at the approximate age of 10 years were examined – they comprised only 133 (52%) of the 254 VLBW survivors.

Years may pass before results are forthcoming and by then there is a risk that the findings may be outdated because of changes in neonatal care practices (the reader is referred to Chapter 1 for a detailed account of recent advances in neonatal care and to Chapter 6 for a discussion on the impact of such advances on longitudinal research of VLBW children). Nevertheless, it is clear that studies that have taken place since the advent of neonatal intensive care have led to advances in the understanding of pathophysiology in the VLBW infants and appropriate measures of intervention. Furthermore, any additions to the knowledge-base of developmental, psychosocial and health outcomes and any progress in assessing the predictive value of data for the later outcomes of VLBW infants will only come from further carefully designed and rigorously conducted follow-up studies.

3.3.2 Bias in serial follow-up studies

The problems associated with conducting longitudinal research into VLBW infants fall into two broad areas:

i. study design
ii. analysis and reporting of the results

Biases can occur at either of these two stages affecting the validity of the findings, but those which occur at the stage of selecting the cohort can reduce the validity of a study which is rigorously conducted in every other way. Bias has been defined as "any process at any stage of inference which tends to produce results or conclusions which differ systematically from the truth" (Sackett, 1979).

3.3.2.1 Selection of the inception cohort

3.3.2.1.1 Referral bias

The majority of VLBW follow-up studies that appear in the literature are hospital based. This is due in no small measure to limited funding for research. Researchers find that it is a more economical way to conduct research to track high risk infants within their own hospital settings. While it is possible that these samples may be representative of the VLBW populations in the geographical areas in which the hospitals are situated, it is rare that this is shown to be the case. Most hospital based VLBW outcome studies are based on small sample sizes with restricted variability in terms of socioeconomic, environmental and cultural factors.

The criteria adopted for deciding whether or not to admit an infant to a NICU vary from hospital to hospital. An important factor in determining whether or not an infant should be admitted to a NICU will be the view that the hospital's obstetricians form regarding its viability. The obstetricians' experience and knowledge of the likelihood of poor outcome will, in turn, influence management decisions for their hospital (Goldenberg et al., 1982).

This does not, however, lead to consistent referral patterns as in some cases the poorest infants are left to die in outlying hospitals as they are considered to sick to transfer (Kitchen et al., 1984; Saigal et al., 1984) while in other cases the poorest infants are transferred to the major regional hospitals with NICU facilities while those infants who appear to be making better progress are left in the outlying hospitals (Saigal, 1982).

The Hammersmith Hospital study (Jongmans et al., 1998) is an interesting study in relation to this issue, as it illustrates some of the advantages as well as the disadvantages of hospital based studies. Unlike most hospital based studies the Hammersmith Hospital study is characterised by a large sample (219 survivors) due to an exceptionally high admission rate of premature infants. As the study was based in the one hospital it was possible to be assured of a uniform level of neonatal care. It also meant that the neonatal status of every child was well documented and that ultrasound scans were evaluated by one person.

The disadvantage of this study is that the findings cannot be generalised to the population of prematurely born infants in general. An additional factor in the case of the Hammersmith Hospital study was an admissions bias whereby an unrepresentatively large proportion of ill infants were included in the study with a larger number showing impairments later on.

In general unless geographically defined populations are studied, whereby all infants are included, there can be no certainty that the sample will be representative of the population. Failure to do so reduces the validity of the findings and the inferences drawn will be less safe. Studying geographically defined populations is preferable as it involves larger numbers, removes referral bias and allows inter hospital comparisons to be made. It is also likely that the findings from population based studies will more generalisable to other settings. The studies of Kitchen et al. (1984) and Saigal et al. (1984, 1982) cited above are population studies set in Australia and Canada respectively. It is precisely because they are population-based studies that they were able to identify the referral patterns operated by different institutions. Hospital based studies are likely to be reporting mortality and morbidity figures that reflect the perinatal and neonatal management of that centre and this can be highly variable across centres.

3.3.2.1.2 Selection bias

Neonatal care is not uniformly available to all VLBW infants for a number of reasons such as medical, geographical and financial. The notion of using mortality rates as a measure of outcome was introduced in Chapter 1. It was suggested treating some, but not all, VLBW infants would be likely to result in reported mortality figures of questionable validity. Many studies document a trend of falling mortality rates across groups of varying birth weights (Wojtulewicz et al., 1993; Hack et al., 1991b,1979; Dillard et al., 1991; Kitchen et al., 1991, 1982; Hoffman & Bennett, 1990; Shapiro et al., 1983; Stewart et al., 1974). There is a problem, however, in reporting falling mortality rates unless information is provided concerning the withholding of treatment because of poor prognosis. Infants who are judged to be at high risk of poor outcome and are denied access to NICU facilities will not figure in the study sample, unless numbers of infants and reasons for their selective treatment are reported on separately. Failure to do so could result in distorted conclusions from the study if the outcome is influenced by removing a significant proportion of live births from the study sample (Saigal et al., 1984; Stewart et al., 1977). This should not affect reported mortality rates for geographically defined studies but it is an important issue as far as hospital and unit based studies are concerned.

3.3.2.1.3 Sociodemographic bias

It is necessary to try to control for socioeconomic status (Broekhuizen et al.,1993; Weisglas-Kuperus et al., 1993b; Vohr, 1992; Parker et al., 1992; Leon, 1991; Buekens et al., 1991; McGaughey et al., 1991; Leonard et al., 1990; Seidman et al., 1990; Ericson et al., 1989; Lewis & Bendersky,1989; Eilers et al.,1986; Silva et al., 1982) and race (Lyon et al., 1994; Collins and David, 1993; James, 1993; Greenberg et al., 1993; Luke et al., 1993; Leff et al., 1992; David, 1990; Gould et al., 1989; Gould & LeRoy, 1988).

Low socioeconomic status is associated with higher mortality and morbidity, especially poorer cognitive ability; some researchers have found it to be the most important determinant in infant development (e.g. Mutch et al., 1993; Ornstein et al., 1991; Eilers et al., 1986). As such the social class and racial distributions of the study group should always be described. Failure so to do makes an interpretation of the comparison of follow-up studies from different centres difficult.

3.3.2.1.4 Control group bias

The majority of follow-up studies are descriptive in nature where, for example, the prevalence of VLBW infants with a particular developmental problem, or who have received a particular form of intervention, are followed up prospectively. In order to place their findings in context, however, the investigators invariably find themselves having to refer to other studies to obtain appropriate comparison groups. Differences in study design, however, can reduce the validity of such comparisons. In trials of clinical intervention it is generally accepted that randomisation is the most appropriate method of control.

In follow-up studies of VLBW infants a variety of comparison groups have been employed; sibling controls (e.g. Eilers, 1986); sociodemographic controls (Klein et al., 1985); historical controls (Jones et al., 1979; Horwood et al., 1998); pre and post-testing of a specific intervention (Wagner et al., 1992; Horwood et al., 1982); VLBW infants with and without the condition under investigation (Tammela et al., 1991).

There is no easy or correct way in which to decide upon the most appropriate comparison group as it will depend upon the research questions being set, nevertheless, a concurrent comparison group is essential for any scientifically robust study even if it does mean additional expense and more time consuming data collection and analysis. Most of the large scale follow up studies in the UK have opted for employing control groups matched by age, gender and classroom environment (e.g. Hall et al., 1995; Pharoah et al., 1994a; Marlow et al., 1989).

When a long term follow up study is making use of standardised assessment instruments it cannot be assumed that the published norms are appropriate to the study cohort (Bill et al., 1986 ; Wolke et al., 1994). In the present study, one strand of investigation concerns the use of published norms versus concurrent norms derived from the control group in terms of gaining the most accurate picture of distributions of IQ and scholastic attainment.

3.3.2.2 Bias affecting investigators, instruments and methods of data collection

3.3.2.2.1 Expectation bias

The investigators, or their research assistants with the responsibility for data collection, should be "blind" with regard to both the initial state and to the results of previous assessments. Objective assessment of, for example, IQ may be prejudiced by knowledge of previous poor scores on tests of intellectual ability. It could be argued that employing standardised assessment which are applied correctly should eliminate any bias of this sort, but ensuring that the assessors are “blind” to the birthweight status of the child provides a further level of assurance that this is so.

3.3.2.2.2 Exposure suspicion bias

When a known association exists between initial state and poor outcome, this may lead to closer and more detailed questioning of, for example, parents by the investigators. Parents of children who received mechanically assisted ventilation may be questioned more closely about breathing problems, for example.

3.3.2.2.3 Diagnostic suspicion bias

This is a similar type of bias to exposure suspicion bias whereby there is a known association between a putative cause and poor outcome; the selectivity of the children who are followed is influenced as a result, for example, intrauterine cocaine exposed VLBW infants are investigated more closely by ultrasound for signs of intracranial haemorrhage.

3.3.2.2.4 Unacceptability bias

People who have been involved in the neonatal care of VLBW infants may be unable to accept the poor outcome of their patients. Arguable, therefore, neonatologists, are the very ones who should not be conducting follow-up studies of VLBW infants – rather they should employ unbiased assessors. On the other hand neonatologists may be able to achieve higher compliance rates than would other assessors and, moreover, they are interested in discovering the results of their neonatal care practices.

3.3.2.2.5 Time course bias

The time at which the children are tested must be appropriate to the outcome being investigated, for example, the incidence of cerebral palsy may be erroneously reported if based on neurological assessments carried out on VLBW children at one year of age as children with transient neurological abnormalities may be included (Stanley, 1982; Nelson and Ellenberg, 1982). Another aspect of timing bias is the duration of the follow-up study. VLBW studies should ideally be run over many years and preferably not less than five years. Although this results in a higher risk of attrition from the study, it allows for the identification of abnormalities which turn out to be transient in nature and, conversely, those where there is a deterioration in functioning over time. Some skills such as cognitive ability are impossible to assess early in life.

3.3.2.3 Analysis and interpretation bias

3.3.2.3.1 Correction for prematurity bias

There is no consensus amongst researchers as to whether there should be correction for prematurity. This refers to the notion that when prematurely born infants are being assessed their ages are taken to be the expected date of delivery (term age equivalent) rather than the actual date of delivery (chronological age). The majority of investigators do correct for the degree of prematurity (e.g. Allen and Alexander, 1990; Zeben-van der Aa, T.M. van, 1989). Some investigators approve of correcting for prematurity up to one year of age and using chronological age thereafter or using a partial correction, for example, using half the difference between chronological age and term age equivalent (Den Ouden, 1991; Siegel, 1983; Foley, 1977). Yet others believe that there should be no correction at all (Miller, 1984) as correction for the degree of prematurity may result in some developmental disabilities or impairments being missed resulting from an over estimation of the infant's performance.

3.3.2.3.2 Data analysis bias

This can occur from selecting inappropriate statistical methods and from failing to adjust for confounding factors before making causal inferences. Bias can also occur from the mishandling of problem cases. Data for VLBW children who have major neuropathology should not be analysed and reported on together with together with the rest of the data as this may result in artificially lowering the mean scores for the total population. Such data must be included in the research notes but it should be analysed and reported on separately (Kiely and Paneth, 1981).

3.3.2.3.3 Interpretation bias

The interpretation of the results of the study should not be influenced by any prejudices on the part of the investigators (Sitthi-amorn and Poshyachinda, 1993). Consideration should also be given to the wider implications of the findings. In a VLBW follow-up study consideration of the wider implications might include, for example, whether the results are robust enough to propose a change in methods of neonatal intervention.

3.3.3 Conclusion regarding the issue of bias in follow up studies

The main problems associated with follow-up studies which have been raised in the preceding discussion are summarised in Table 3.3.3.

It is not always possible to avoid every conceivable source of bias, yet attention to study design and awareness of these issues are keys to maintaining good validity. This in turn will allow for more definitive statements to be made about the research questions under investigation.

Table 3.3.3
Principal difficulties in conducting follow-up studies of VLBW infants (based on Aylward et al., 1989)

1.	inadequate description of the subject population
2.	perinatal course not considered
3.	single hospital samples - not populations
4.	lack of appropriate comparison groups
5.	excessively high attrition rates
6.	no assessment or adjustment for environment
7.	duration of follow-up insufficient
8.	outcome measures poorly specified
9.	variability in diagnostic criteria
10.	no consensus on correction for prematurity
11.	profoundly impaired children included in mean score
12.	inappropriate statistical analysis
13.	spurious conclusions drawn from results

3.4 Lack of progress in unifying study design and methods of reporting

As mentioned at the outset of this chapter a major difficulty in reviewing the literature on follow-up studies is that almost every study differs in its design and in its reporting of its findings. More than a quarter of a century ago some investigators were already trying to take these issues into consideration when designing their studies and reporting their findings (e.g. Drillien, 1964). While there has been some move towards a conventional format for reporting findings from follow-up studies, in general the picture remains little changed. The discussion that follows concerning mortality rates as an outcome measure for VLBW infants illustrates once again the difficulties created by the adoption of differing methodologies.

3.5 Mortality is not an unequivocal outcome measure

The origins of research on low birthweight infants were discussed in Chapter 1. It was noted that mortality was the main outcome measure in early studies. While interested gradually moved to other outcome measures, many studies continue to report mortality data. There are few studies, however, that combine fetal and neonatal mortality. This is especially true for studies reporting upon infants of <28 weeks gestation. Furthermore, there appear to be no reports that combine such mortality data with morbidity data.

3.5.1 Mortality data should include infants who are dead at delivery

If counting only starts from birth, there will be an absence of information about the percentage of infants already lost. This will also confound postnatal mortality and morbidity data – as some mortality and morbidity will be "prevented" if counting only starts from birth (Wariyar et al., 1989; EC Working Group on the Very Low Birthweight Infant, 1990).

The literature is characterised by differences in the way in which mortality data are reported. For example, some authors reporting from neonatal intensive care units (NICUs) will count mortality (i.e. all deaths) (e.g. Kitchen et al., 1987; Hack et al., 1986; Yu et al., 1986) while others will report upon infants admitted to their NICU but not including those who died in transit (Astbury et al., 1983; Calame et al., 1986;

Cooke et al., 1988; Haas et al., 1986; Ferrara et al., 1989; Hack et al., 1983; Largo et al., 1989; Lefebvre et al., 1988; Portnoy et al., 1988; Ross et al., 1985; Vekerdy-Lakatos, et al., 1989; Marlow and Chiswick, 1988).

A degree of caution is necessary, therefore, when reviewing studies on mortality rates. Unless hospital records are carefully examined very immature infants who might have died in the delivery room or been misclassified as stillbirths will not be included in livebirth statistics (Horwood et al., 1982).

3.5.2 Mortality data should include postneonatal deaths

It is sometimes forgotten that it is not only the reporting of neonatal mortality that is important but also the reporting of postneonatal mortality. Postneonatal death is associated with low birthweight and preterm birth and is often the result of a postponement of death (Cooke, 1990; Hack & Fanaroff, 1986; Mutch, Newdick, Lodwick & Chalmers, 1986; Shapiro et al., 1983; Horwood et al., 1982; Morgan, 1985). Another category of infants who are often excluded from published reports are those with fatal congenital malformations – this issue has been investigated and documented by an Australian group (Kitchen et al., 1985). Again, failure to include postneonatal deaths will confound reports of mortality and morbidity rates.

3.5.3 Registration of mortality is influenced by the current lowest limit of viability

An associated complication is that the registration of mortality in liveborn infants will depend upon the supposed lowest limit of viability (Fenton et al., 1990; Ruys et al., 1989; Goldenberg, Nelson, Dyer & Wayne, 1982). This particular problem of recording the deaths of very immature infants was reported in a study of all infants of less that 20 weeks gestation and less than 750g birthweight delivered in a perinatal centre between 1982 and 1985 (Hack & Fanaroff, 1986).

Hack and Fanaroff were involved in an examination of the problem of defining the lower limits of viability for offering aggressive intervention in NICUs. They discovered that while no particular policy on resuscitation existed there appeared to have been a subtle change over time whereby progressively smaller and more immature infants were provided with aggressive neonatal intervention. They reported that the yearly mortality rates changed very little but that the period between delivery and death increased over time. As a result, one of the conclusions reached by the authors was that intervening aggressively for infants born on the limits of viability is likely to increase the costs of hospitalisation.

It was also reported that the decision to resuscitate infants or to transfer them to NICU was subject to a selection bias – as 57% of the infants, closest to the limits of viability, were not resuscitated but allowed to die following delivery. The authors note that if these infants had not been included in mortality figures then the findings would have appeared unduly optimistic in that there would have been a reported 48% survival rate rather than the actual 20% survival rate. This emphasises the need for all livebirths to be reported upon and reaffirms that hospital-based studies are likely have less validity than population-based studies.

3.6 Problems associated with a lack of uniformity in the use of terminology on morbidity.

Chapter 2 of this thesis provided a broad review of VLBW research – with a particular focus on the last two decades. One of the major difficulties in reviewing the literature in relation to morbidity relates to a lack of consistency in use of terminology and definitions across studies.

Terms frequently encountered include impairment, disability and handicap. The World Health Organisation offers definitions of these terms and these are outlined below. While some studies state explicitly that it is the WHO definitions that apply in their reports, this is not always the case. One of the difficulties in comparing the findings of VLBW studies is, therefore, that although authors may employ similar terminology they do not necessarily define their terms in the same way.

The definitions of the WHO for the terms (i) impairment, (ii) disability and (iii) handicap are as follows:

(i) *impairment*: any loss or abnormality of psychological, physiological or anatomical structure or function;

(ii) *disability*: any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being:

(iii) *handicap*: a disadvantage for a given individual, resulting from an impairment or disability, that limits or prevents the fulfilment of a role that is normal (depending on age, sex, and social and cultural factors) for that individual.

Disability refers particularly to activities and behaviours associated with everyday life such as walking, seeing and listening, speaking, self care, and functioning within a group of peers. It is level of function in these integrated activities that are expected of the person or the body as a whole that determine whether an impairment causes a disability.

The term disability does not take into account the social consequences of any restriction – it is purely concerned with the individual performance.

A minor disability is one that does not seriously or continuously affect the functional performance and activity of the individual. A major disability is one that has a serious or continuous effect on functional performance and activity.

An individual is described as having a handicap when disadvantage is experienced in society as a result of a lack of orientation, physical independence, mobility or social integration. Severe learning difficulties or severe cerebral palsy would be likely to constitute a handicap.

A minor handicap is one that interferes, but not seriously, with everyday life and does not require extensive individual support. A child with moderate learning difficulties who requires special educational provision but who is able to function normally within the family and to communicate with other children or a child with cerebral palsy who requires assistance with mobility would be considered to have a minor handicap.

A handicap that is described as major is one that interferes seriously with everyday life and it imposes a severe burden on the child, those who support the child and society. A child who requires total care and assistance in almost all aspects of everyday life or one with severe or profound learning difficulties is considered to have a major handicap.

Those children who require special educational provision as a result of one or more impairments or disabilities are considered to have, at least, a minor handicap.

3.7 Methodological issues – concluding remarks

The foregoing does not represent an exhaustive account of all the methodological issues that pertain to follow up studies of VLBW children. It does, however, cover the main issues that need to be considered in devising such a study and comparing its findings with those of other studies. Some of the difficulties are almost impossible to overcome such as comparing studies which have employed different methodologies. However, the existence of such difficulties can at least be highlighted when the findings of the study are being reported.

Methodological issues that relate to study design are easier to address. For example, employing a matched control group reduces the risk that the results will be confounded by social or cultural factors. It also allows concurrent norms to be derived rather than relying on published norms for any tests which are used.

The present study, representing the eight year follow up of the Scottish Low Birthweight Study, attempts to address as many of these methodological concerns as possible. It is a national cohort study, comprising all surviving children born in Scotland in 1984 – who are still resident in Scotland. A matched control group was recruited whereby there were two comparison children for every index child. Matching was on the basis of gender, age and classroom environment. Suitable matched control children could not be identified for children in special education – who tended to have more serious problems. The results of the assessments of children in special education are reported in a separate section of the results chapter in this thesis. Had their results been analysed together with the rest of the cohort it is likely that the scores for the index group would have been artificially lowered.

Attrition rates were kept to a minimum and although a 100% follow up was not achieved, the actual rate of 96% is at least as good as any other follow up study in the literature (eg. Verloove-Vanhorick et al., 1986).

The follow up of the Scottish VLBW cohort has continued well into the primary school years. By eight to nine years of age children are expected to have acquired basic literacy and numeracy skills. However, some VLBW children who were thought to be unimpaired in their pre school years may by this stage be starting to manifest more subtle neurological impairments in the form of school failure as the demands placed upon them by formal education increase.

The use of terminology and the definitions employed it this thesis follows World Health Organisation conventions.

(The strengths and weaknesses of the present study are given further consideration in Chapter 6 of this thesis.)

The first section of the following chapter provides a detailed description of the Scottish Low Birthweight Study cohort, from its inception in 1984 through the eight year follow up. The second section provides a comprehensive account of the methodologies adopted in this study.

Chapter Four

The Scottish Low Birthweight Study - Methodology

4.1 The Population Base

4.1.1 The study cohort as presently defined:

The cohort for the eight-year follow-up of this study comprised all surviving children born in Scotland in 1984 with birth weights less than 1500g. Those surviving children who had moved away from Scotland since their birth were not followed up because their educational experience would have been different to the rest of the cohort being educated under the Scottish system. A further reasons for not following up those who had moved away related to the additional cost that would have been incurred. These children were not, therefore, considered part of the target population.

4.1.2 Changes to the Scottish Low Birthweight Study cohort

In the early stages of the project there was collaboration with neonatal care physicians throughout Scotland. Every maternity unit in Scotland provided information on all infants weighing <1750g and this information was cross checked with data which is routinely collected by the Information Statistics Division of the Common Services Agency. This information is, in turn, linked to the Registrar General for Scotland's record of births and deaths.

Thus, from the inception of the Scottish Low Birthweight Study until submission of the proposal for the present follow-up, the birthweight criterion for cohort selection had been <1750g. However, at this stage a decision was taken to reduce the size of the cohort. Two factors led to this decision:

i. the creation of a comparison group comprising two children for every index child (explained in detail in section 4.2.5.2.2 of this chapter) would have resulted in a prohibitively large number of assessments to be performed - not far short of 3000. This would have created even greater difficulties if the assessments were to be carried out within the time limit which the study group had set itself for data collection, namely, one calendar year.

ii. the Medical Research Council, who funded the study, were concerned at the cost of such a follow-up but were keen to continue to support the project if the cost could be reduced. As the main strength of the study lies in the fact that it encompasses a geographically defined area, the option of selecting one, or a number of, smaller areas while maintaining the other criteria for cohort selection was not attractive. Another possibility would have been to carry out a further follow-up of the LBW population without the inclusion of a comparison group. Again this option was rejected as the inclusion of such a group would allow for a more robust statistical analysis of the results and would also assist in the protection of the anonymity of the index children, given that the assessments were to be carried out in school.

In the event it was decided to include a comparison group and reduce the birthweight criterion to <1500g, the internationally accepted threshold for VLBW. Thus, while the size of the cohort was reduced by approximately 50% the national character of the study was preserved.

4.1.3 The inception cohort

There were 1044 registered births in Scotland in 1984 of infants weighing <1750g, of whom 908 survived. Infants with birthweights <1750g accounted for 1.4% of live births in Scotland in this year. Not all of these infants were entered into the study at this time; one mother refused to give her consent, one child was missed and the study was not made aware of a further ten infants until it was too late to include them. Thus, of the 908 liveborn infants 896 were entered into the study and 12 were not.

A research health visitor collected perinatal data retrospectively from obstetric and neonatal case notes. Of the 896 infants who were entered into the study 194 died by the end of the first week and a further three by the end of the neonatal period. 661 (74%) survived to be discharged home from the neonatal unit.

Approximately one third of deaths occurred in the first 24 hours. However, of those infants weighing <1000 g 45% died in the first day but infants with birthweights >=1000 g were more likely to die later in the neonatal and postneonatal periods. Table 4.1.3

The number of birth, deaths and survival rates per 1000 live births of infants with birthweights <1750 g, in Scotland in 1984: death and survival rates by birthweight group

	Birthweight			
	<1000g	1000-1499g	1500-1749g	Total
No. of livebirths	204	397	295	896
No. of neonatal deaths (rate/1000 livebirths)	126 (168)	71 (178)	20 (68)	217 (242)
No. of postneonatal deaths	14	13	9	36
Deaths 1-2 years	4	1	1	6
Total deaths	144	85	30	259
Survival to 28 days (rate/1000 livebirths	78 (382)	326 (821)	275 (932)	679 (758)
Survival to 2 years (rate/1000 livebirths	60 (294)	312 (786)	265 (898)	637 (710)

Source: based on McIlwaine et al., 1989.

4.1.4 The study group at two years of age

94% of infants who survived one week were alive at discharge and 91% were alive at two years (McIlwaine et al, 1989). So by two years of age 637 children were still alive, representing 71% of the initial birth cohort.

At two years of age only 81% of the target cohort of 637 children received a medical assessment, although a further 10% were examined by health visitors. For the purposes of reporting the findings the children were assigned to three groups:

i. <1000 g;
ii. >=1000 g <1500 g;
iii. >=1500 g <1750 g.

Of the 515 children who were medically examined 353 (68%) had no detectable problems: 57% in the <1000 g group; 65% in the >=1000 g <1500 g group and 75% in the >=1500 g <1750 g. In total 162 children were reported to have some impairment but half of these children were not disabled to any significant extent.

Table 4.1.5

Summary of two-year outcomes based on medical assessments: numbers (%) of children with impairments by birthweight group*

	Birthweight			
	<1000g	1000-1499g	1500-1749g	Total
No. of livebirths	204	397	295	896
Neonatal survivors	78	326	275	679 (76)
Survivors at 2 years	60	312	265	637 (71)
Total seen	54 (90.0)	253 (80.8)	206 (78.0)	513 (80.5)
Unproblematic at 2 years	31 (57.4)	165 (65.2)	155 (75.2)	351 (68.4)
Some problem at 2 years	23	88	51	162
Motor deficit of central origin:	8 (14.8)	25 (9.9)	12 (5.8)	45 (8.8)
Severe disability	2	5	9	16
Moderate disability	4	18	3	25
Impairment but no disability	2	2	0	4
Vision loss:				
Retinopathy of prematurity				
- blind	3	2	0	5
- partially sighted	2	2	0	4
Congenital visual defect	1	2	1	4
Cortical visual impairment	0	0	1	1
Refractive error	1	2	0	3
Squint alone	2	8	4	14
Squint and other impairment	5	13	6	24
Hearing loss:				
Deaf – using aids	2	1	2	5
Deaf – moderate loss	0	6	3	9
Medical problems	2	10	6	18
Developmental delay:				
- severe	1	2	1	4
- moderate	3	8	1	12
- mild	4	32	21	57

Source: based on McIlwaine et al.,1989.

*These impairments are not mutually exclusive

4.1.5 The nature of impairments

i. Motor deficit of central origin: 45 children (8.8%) were diagnosed with this condition. 16 (3%) of these children had cerebral palsy with marked functional loss and a further 25 (5%) had a neurological deficit resulting in moderate functional loss; four children had neurological signs but no functional loss.

ii. Visual deficit: 17 children (3%) were identified as having some form or other of visual impairment. Retinopathy of prematurity was diagnosed in nine children (1.8%) five of these children were blind. One child was diagnosed as being cortically blind and four children had congenital eye lesions.

iii. Hearing deficit: 14 children were found to be deaf, five of these children were using hearing aids. All the hearing impaired children, even those children with hearing aids, were found to have considerable delay of their language development.

iv. Other major medical conditions: 18 children had medical conditions which were described as significant, resulting in repeated re-hospitalisation because of recurrent respiratory illness, seizures and the sequelae of necrotising enterocolitis among other conditions.

v. Lesser morbidities: of the 162 children diagnosed as being impaired 57 (11%) were described as mildly delayed in their development and 14 children had only an isolated squint.

4.1.6 The study group at four years of age

By the four year follow-up 636 (71%) of the low birthweight cohort had survived (Scottish Low Birthweight Study Group, 1992a).

The mean age of the population at this follow-up was 4.5 years and 611 children were assessed; representing 96% of the target cohort. One child, who was assessed as being multiply handicapped at two years, died an accidental death at four years.

Table 4.1.6.1

The number of deaths and survival rates per 1000 live births at 4.5 years of age of the Scottish Low Birthweight Cohort (<1750 g): death and survival rates by birthweight group

	Birthweight			
	<1000g	1000-1499g	1500-1749g	Total
Deaths birth to 2 years	144	85	30	259
Deaths 2 to 4 years	0	1	0	1
Total deaths	144	86	30	260
Survival to 4.5 years (rate/1000 livebirths	60 (294)	311 (783)	265 (898)	636 (710)
No. assessed at 4.5 years (%)	60 (100.0)	267 (95.5)	254 (95.8)	611 (96.0)

Source: based on the Scottish Low Birthweight Study Group, 1992a

16% of the children were diagnosed as being disabled, of these 47 had cerebral palsy, among those not overtly disabled there was a high prevalence of poor neuromotor functioning and this was related to birth weight. Seven of the children were assessed as being blind and 11 as being deaf and using hearing aids.

Table 4.1.6.2

Summary of disability ratings at 4.5 years of age: numbers (%) of children by birthweight group

	Birthweight			
	<1000g	1000-1499g	1500-1749g	Total
Survivors assessed at 4.5 years	60	297	254	611
Unproblematic	25 (41.7)	162 (54.4)	147 (58.1)	334 (54.7)
Impaired but not disabled	15 (25.0)	90 (30.2)	69 (27.3)	174 (28.5)
Moderate disability:				
single system	10 (16.7)	22 (7.4)	18 (7.1)	50 (8.2)
multiple systems	2 (3.3)	10 (3.4)	5 (2.0)	17 (2.8)
Severe disability:				
single system	3 (5.0)	7 (2.3)	6 (2.4)	16 (2.6)
multiple systems	5 (8.3)	7 (2.3)	8 (3.2)	20 (3.3)

Source: based on the Scottish Low Birthweight Study Group, 1992a

Table 4.1.6.3

Characteristics of the Scottish Low Birthweight cohort (<1750 g) at 4.5 years of age by birthweight group

	Birthweight			
	<1000g	1000-1499g	1500-1749g	Total
Gender ratio at birth (M:F)	0.92	1.19	1.07	1.08
Gender ratio of survivors (M:F)	0.67	1.06	1.01	0.99
Birth number: % singleton at birth	72.1	78.4	83.0	78.5
Mean maternal age at delivery (years)	25.2	25.6	25.5	25.5
Social class of father at 4years (%):				
I and II	18.3	14.4	19.0	16.7
III non manual	8.3	5.7	5.5	5.9
III manual	23.3	35.6	30.4	32.2
IV and V	20.0	19.1	18.2	18.8
Single parents at four years (%)	15.0	11.1	13.8	12.6
Small for gestational age (%<10th centile):				
At birth	22.4	30.4	38.1	31.4
Survivors	34.8	35.5	38.0	36.5
Mean (SD) age at assessment (months)	55.3 (2.2)	55.5 (2.6)	55.6 (2.9)	55.5 (2.7)

Source: based on the Scottish Low Birthweight Study Group, 1992a

Growth measurements taken at the four year follow up included, height, weight and head circumference. The mean values for the cohort were lower than the standard population mean on all measures. The downward shift in the distributions for all of the growth measures was accompanied by a negative skewing for the height distribution.

4.1.7 The study group at eight years of age

One child died of AIDS between the four-year follow-up and the present phase of the study. As a result of the revised criteria for cohort membership only those children who had birthweights <1500g are included and this is reflected in the summary table below.

Table 4.1.7

The number of deaths, survival rates per 1000 live births and success of follow-up at 8.9 years of age of the Scottish Low Birthweight Cohort (<1500 g): death and survival rates by birthweight group

	Birthweight			
	<1000g	1000-1499g	1500-1749g	Total (excl. 1500-1749g)
No of live births	204	397	(295)	601
Deaths birth-4.5 years	144	86	(30)	230
Deaths 4.5-8.9 years	1	0	N/A	1
Total deaths	145	86	N/A	231
Survival to 8.9 years (rate/1000 livebirths)	59 (289.2)	311 (783.3)	N/A N/A	370 (615.6)
No of children no longer resident in Scotland				30
No of children adopted and untraceable for legal reasons				2
Target population				338
No assessed at 8.9 years (% of target population)	53	298	N/A	324 (96%)

The hypotheses are presented in Chapters 2 of this thesis. They relates to the cognitive, scholastic and neuromotor outcomes of the VLBW cohort at eight years of age. The performance of the index cohort in these developmental domains is compared with that of their heavier birthweight classroom peers.

The second section of this chapter provides a detailed account of the methodology adopted including study design, assessment materials employed and statistical analysis.

4. 2 Study design and implementation

4.2.1 Stages of development of design and implementation

The stages involved in setting up and undertaking the study were as follows:

i. formulation of research questions and development of study design;
ii. submission of the research proposal to the grant awarding body, namely, The Medical Research Council;
iii. submission of revised research proposal to the grant awarding body;
iv. submission of the research proposal to the medical ethics committee of the health boards of Scotland and the directors of education of the regional and divisional education authorities;
v. training of the research assistants responsible for the collection of the psychological and educational data;
vi. training of the research nurses responsible for the collection of the health and growth data;
vii. distribution of questionnaires to teachers and parent;
viii. arrangement of school visits by psychologists and nurses;
ix. coding of data and data entry
x. data cleaning
xi. data analysis
xii. reporting

4.2.2 The Scottish Low Birthweight Study Group

4.2.2.1 Study personnel involved at the eight year follow up

The study group comprised the following members:

educational psychologist x 1 (the author)
assistant psychologists x 2
medical co-ordinator x 1 (grant holder)
research nurses x 3
study co-ordinator x 1
statistician x 1

4.2.2.2 The role of the author

The design of the study, including assessment of the index and comparison children in terms of cognitive, scholastic and neuromotor functioning at eight years of age was entirely the responsibility of the author. Most of the psychological assessment was undertaken by the author, producing more than 50% of this large dataset, with two psychology graduates being recruited to assist with the rest of the data collection. The author was responsible (a) for training these assistant psychologists in the standardised presentation of the assessment instruments and (b) for quality assurance – supervising and monitoring their performance throughout the data collection phase. The data were coded and the dataset compiled by the author, with ownership of the psychological dataset of the eight year follow up being the author's. All statistical analyses were carried out by the author.

The author's interest in the study directly relates to the eight year follow up. Clearly, however, the eight year follow up takes place within the context of a longitudinal study. The performance of the index children is, therefore, considered in relation to the findings of earlier phases of the study. However, throughout this thesis reference is made to the difficulty in investigating changes over time in the Scottish VLBW cohort. Principally this relates to the absence of a comparison group until the present phase of the study and the knowledge that published test norms are not particularly representative of the eight year Scottish comparison group – especially in terms of motor functioning. This causes difficulty in, for example, comparing distributions of cognitive, scholastic and motor performance between four years of age (based on published test norms) and the eight years of age (based on concurrent norms derived from the comparison group). Thus, while the cohort is discussed in relation to earlier phases of the study, the focus in this thesis is very much centred on the eight year follow up and an investigation of some associated methodological issues.

4.2.3 Generation of research questions

A formal statement of the hypotheses is presented in chapter 2. These were derived in large part from the findings of the four-year follow-up of the Scottish low birthweight cohort. Many differences were found between the index children and published norms, and these differences related to all aspects of child development.

It was hypothesised that the absence of such differences at eight years would be suggestive of transient developmental delay as opposed to longer term impairment. Conversely, absence of catch up at eight-years would be indicative of more enduring developmental problems.

Other research questions arose following discussions with advisers from other specialties and from reports published in the literature by other study groups. For the most part the research questions that arose following discussions with advisers fall outwith the scope of this thesis although the questions concerning the neurological status of the children in relation to both motor functioning and educational attainment were formulated following such discussions. Important strands of investigation in this thesis were derived from surveying the literature, for example, the comparison of IQ distributions using published norms and concurrent norms derived from the comparison group and the comparison of performance between small for gestational age and appropriate for gestational age children and gender differences.

4.2.4 Study design

The study design was shaped by the four year follow up of the Scottish Low Birthweight Study, the important difference being the inclusion of a comparison group. Once again a geographically defined population was chosen as the inception cohort for the methodological reasons discussed in Chapter 3. The inclusion of a comparison group comprising two classroom peers for every index child was made both to allow for a more rigorous statistical analysis of the data and to help protect the anonymity of the VLBW children. The survival rates for the cohort are presented above and a detailed account of the characteristics of the VLBW population and comparison group are presented at the start of Chapter 5.

4.2.5 Method

4.2.5.1 Permission to undertake the study

Permission was sought from both from the Research Ethics Committees for the Health Boards of Scotland and from the Directors of Education of the regional education authorities to approach the families and schools.

4.2.5.2 Identification of index and comparison children

4.2.5.2.1 Identification of the index children

The index children were identified from the records of the four-year follow-up. Their addresses were used to contact the zoned primary schools for the appropriate catchment area. (The records of the four year follow up included the name of the primary school in which the child was expected to be enrolled.) In those cases where the children were not registered in the contact school, and where those schools were not able to advise of a new address, the General Registers Office was contacted. Occasionally it was necessary to contact general practitioners for assistance. Reference to records still held in a GP's office provided the most recent family address, otherwise a request for the transfer of medical notes allowed for the new GP to be contacted. Overall, four children from the target cohort of 338 proved untraceable.

4.2.5.2.2 Identification of the comparison children

The headteacher of each school was asked to confirm that the index child was registered with them and to identify two children being taught in the same class, of the same gender and nearest in dates of birth to the index child. (Other criteria for matching which were also given consideration were ethnic background, socioeconomic status and family structure. The number of ethnic minority children in the study was very small and, as the non-white population of Scotland is also small, to match rigorously by ethnic background would have meant having no control children for some of the non-white index children. The socioeconomic status and family structure of the comparison children's families were unknown both to the school and the study group prior to their enrolment in the study. As headteachers were helping with the identification of the comparison children it did not seem reasonable to use selection criteria which were not immediately available to them from schools records.)

4.2.5.3 Procedure for gaining parental consent

Headteachers were requested to send forms asking for their participation to the families of the index and comparison children in pre-paid envelopes. Parents were provided with information about the study, a reply slip and a pre-paid envelope addressed to the school. In the case of a refusal on the part of an index child's parent(s), headteachers notified the study group who made one further approach to the family directly. In the case of refusal on the part of the parent(s) of a comparison child, headteachers were instructed to identify the child of the same gender with the next nearest date of birth to the index child and to seek permission from this child's family. Headteachers were asked to return the three signed reply slips to the study co-ordinator once they had been received.

4.2.5.4 Organisation of data collection

The study co-ordinator made arrangements with headteachers for visits by the psychologists once permission for assessment had been received from the parent(s) of all three children in a triad.

At the same time questionnaires for completion by the teachers were sent to the schools and questionnaires for completion by parent(s) were sent to the family homes. Teachers were requested to have questionnaires completed and ready for collection by the time of the psychologists visit. Parents were informed of the date of the psychologist's visit and requested to complete and return their questionnaires to the school on or before this date.

4.2.6 The test protocol:

the assessment comprised four elements

a) motor functioning

b) cognitive skills and educational progress

c) neurological status

d) self perception

4.2.6.1 Motor functioning

Motor functioning was assessed using the Movement Assessment Battery for Children (Movement ABC) (Henderson and Sugden, 1992). This test was used at the four-year follow-up under its previous guise, the Test of Motor Impairment (TOMI) (Stott, Moyes and Henderson, 1984).

Eight activities are used to explore three different aspects of motor functioning; gross motor movement, fine motor control and balance.

Gross motor movement is assessed by:

Two-handed catch - the child is required to throw a tennis ball against a wall from a distance of six feet and catch it in both hands without allowing it to bounce first and without catching it against the chest.

Throwing the beanbag - from a distance of eight feet the child is required to throw a beanbag into a target box with the preferred hand.

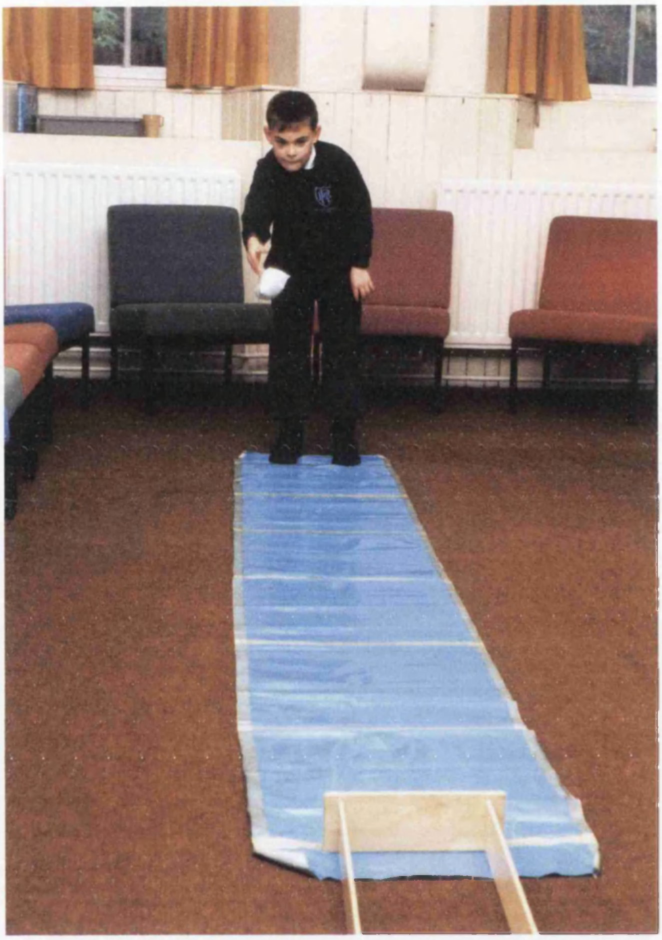

Figure 4.2.6.1.1 Throwing the beanbag (Movement ABC)

Fine motor control/manual dexterity is assessed by:

Threading nuts onto a bolt - this is a timed activity whereby the child must thread three nuts onto a bolt as quickly as possible. Only one bolt may be threaded at a time and it must by fully tightened before threading the next nut.

Flower trail - a flower pattern described by two parallel lines is presented to the child. The task requires the child to draw around the flower trail without crossing the lines

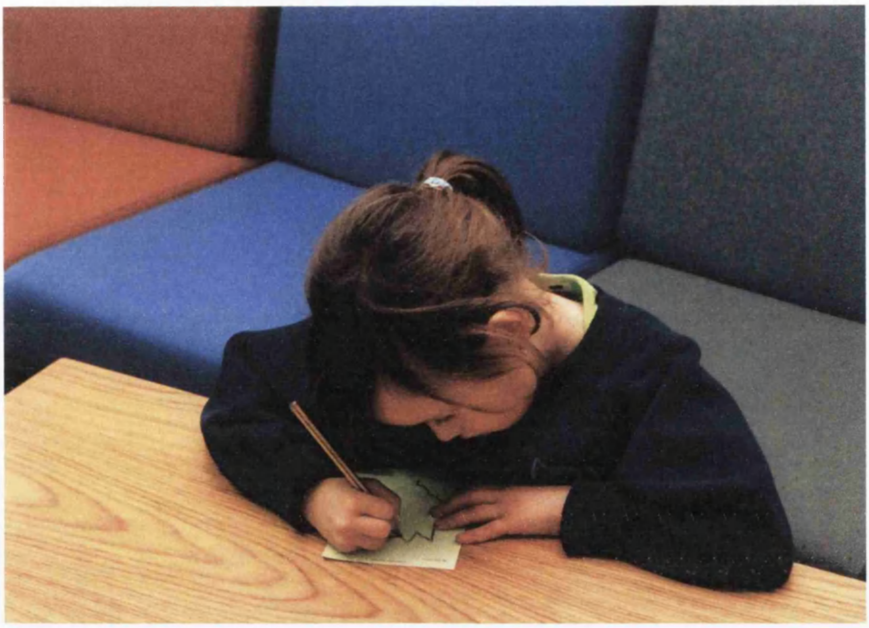

Figure 4.2.6.1.2 Flower trail (Movement ABC)

Peg board - a sixteen-hole peg board 4 x 4 is presented to the child with the furthest row empty of pegs. The child is required to move all the pegs forward one row at a time as quickly as possible always starting from the left. The task is done first with the preferred hand and repeated with the non-preferred hand.

Balance is assessed by:

One board balance - this task assesses static balance. The child is required to balance on a board one foot in length by three inches wide. The board has a flat upper surface but a one inch wide spar along the centre of the underside, thus making the board unstable laterally. The board is placed on a firm floor surface such as linoleum or wood, the child can be supported until balance is achieved and timing then commences until either balance is lost or the other foot touches the ground.

Figure 4.2.6.1.3 One board balance (Movement ABC)

hopping - this assesses dynamic balance. A mat eight feet long by 18 inches wide is placed on the floor. The mat is divided into five squares. The child stands on the preferred leg in the first square and takes one hop, and only one hop, in each of the remaining squares. The exercise is repeated for the non-preferred leg.

ball balance - also assessing dynamic balance. The mat described above remains in place on the floor. The child is provided with a thin, flat piece of wood six inches square which is placed on the flat palm of the preferred hand. A tennis ball is provided which is placed on top of the board. The objective is to circumnavigate the mat without dropping the tennis ball.

4.2.6.2 Cognitive ability

The cognitive skills of the children were assessed using selected age-appropriate items from the British Ability Scales (BAS) (Elliot et al, 1979). Items were selected to fulfil two functions:

1. to enable an assessment of those cognitive skills which had been tested at four years of age to be re-tested;
2. to allow for the estimation of an IQ score.

The scales selected were the following:

Recall of digits - a test of short-term auditory memory storage capacity;

Recall of designs - a test of short term visual memory;

Similarities - a test of verbal reasoning skills;

Matrices - a test of visual reasoning skills;

Figure 4.2.6.2.1 Matrices (British Ability Scales)

Speed of information processing - a test of symbol storage and manipulation in short term memory/working memory under a time demand;

Block design - a test of spatial visualisation;

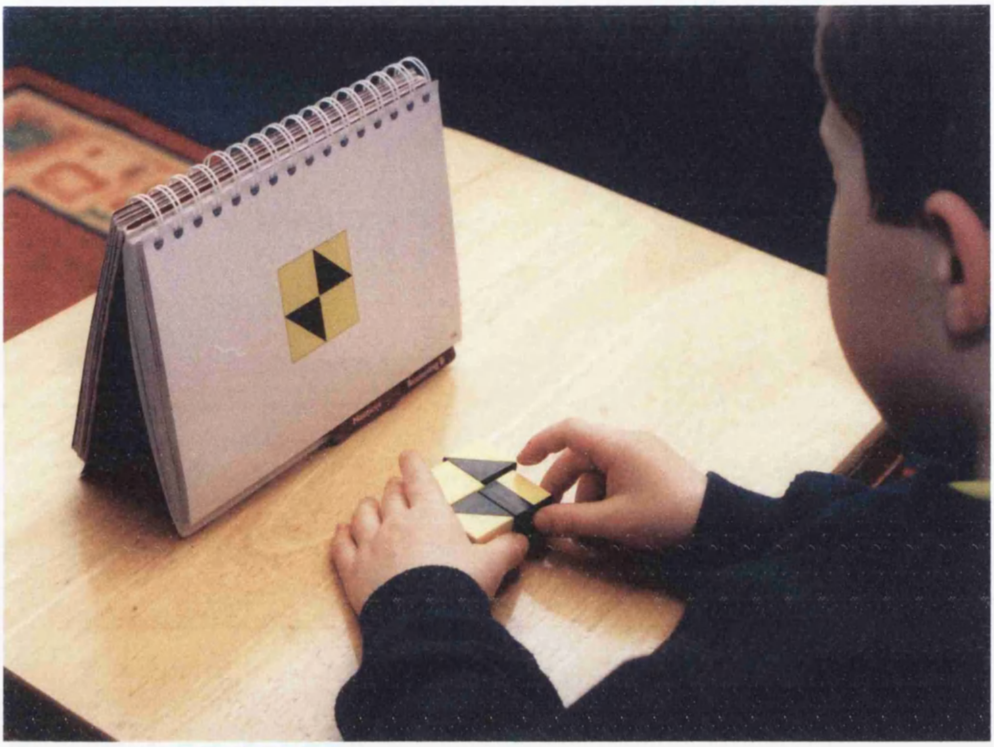

Figure 4.2.6.2.2 Block Design (British Ability Scales)

Word definitions - a test of retrieval of information from long-term memory.

Two additional scales from the BAS were selected to measure educational progress:
Basic number skills - for numeracy;

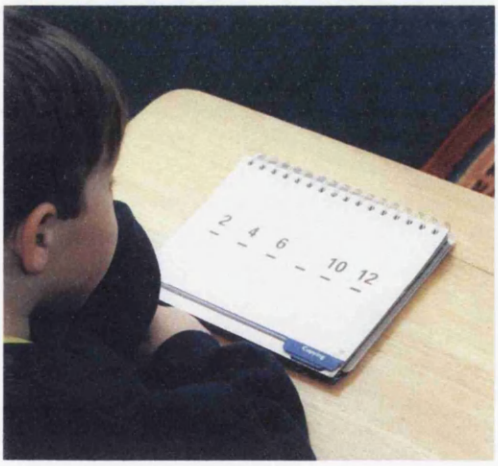

Figure 4.2.6.2.3 Basic Number Skills (British Ability Scales)

Word reading - for literacy.

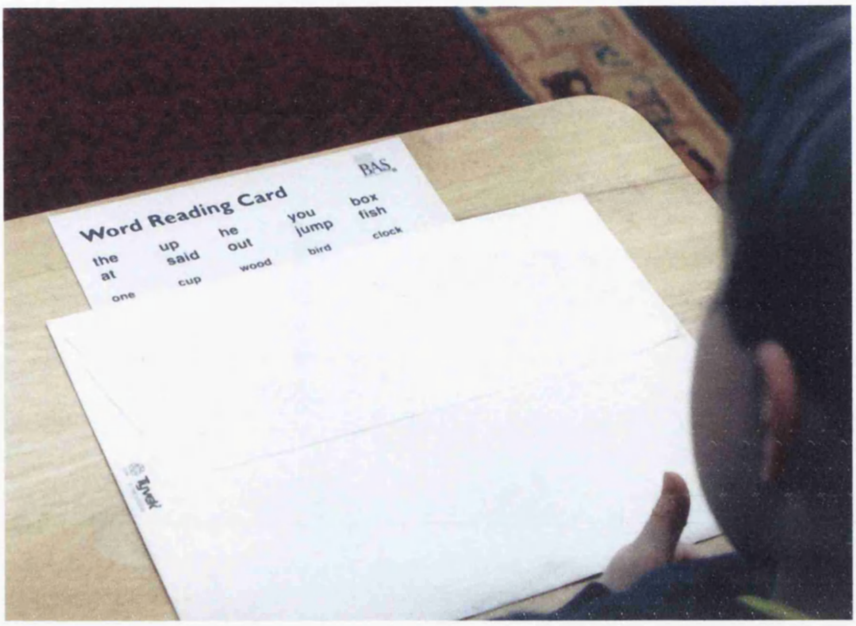

Figure 4.2.6.2.4 Word Reading (British Ability Scales)

4.2.6.3 Neurological status

Neurological status was assessed using the Quick Neurological Screening Test (QNST)(Mutti et al, 1978). This is an assessment tool designed to be used by psychologists to identify children as young as five years old who are at risk of experiencing learning difficulties as a result of their underlying neurological status. The items included in the test are as follows:

Hand skill - a paper and pencil exercise to examine hand preference and to identify tremors and/or visual impairment

Figure recognition - a paper and pencil test to examine fine motor control from the reproduction of geometrical figures

Palm form - to identify any tactile deficits by an inability to report numbers being drawn on the palm of the hand with eyes closed

Eye tracking - to identify immature visual sensory-motor skills by an inability to track a moving object laterally and/or horizontally

Sound patterns - to identify immature auditory sensory-motor skills by an inability to reproduce patterns of sounds by tapping hands on knees

Finger to nose - to identify difficulties of knowledge of body position and orientation in space by failure to move hand from examiner's finger to own nose with eyes closed

Thumb and finger circle - to identify finger localization problems by an inability to touch thumb to each of the other fingers in turn

Double simultaneous stimulation of hand and cheek - to identify problems with intrabody communication and tactile deficits by inability to detect touch to hand and cheek simultaneously.

Rapidly reversing repetitive hand movements - to identify motor planning difficulties by inability to move hand simultaneously in a rapid reversing movement

Arm and leg extensions - to identify poor motor planning by failure to hold arms and legs extended for 30 seconds

Tandem walk - to identify gross motor movement problems by difficulty in walking in a heel-to-toe fashion across a room

Standing on one leg - to identify problems of balance and body awareness by difficulty in balancing on one leg at a time with eyes open and with eyes closed

Skipping - to identify gross motor movement problems by difficulty in skipping across a room

Left-right discrimination and hand-eye-foot preference - to verify that discrimination and preference have been established and to identify any asymmetries between hand, eye and foot

Behaviour - to identify behavioural irregularities which may result from physical problems rather than to experiential or environmental impact

Raw scores for each item are re-coded as either 'high', 'suspicious' or 'low'. The authors of the QNST suggest that each item with a 'high' score has educational implications for the child. Furthermore, an overall neurological score can be achieved by combining the results from all the scales. The purpose of administering the QNST in this study was to gain some knowledge about the neurological status of those children with poor motor functioning. However, it also afforded an opportunity to investigate whether or not the QNST does what it purports to do, that is, identify children with a neurological basis for learning difficulties (this issue is discussed in Chapter 6).

4.2.6.4 Self perception

Self perception was investigated using a modified version of the Self-Perception Profile for Children (Harter, 1985). Harter's original test had to be shortened, simplified and de-Americanised to make it appropriate for the age-group of children in the study.

This test is mentioned because it formed a part of the test protocol, however, the findings of this part of the investigation do not fall within the bounds of this thesis (the reader is referred to Hall, 1994).

4.2.7 Training of the research assistants

Training on the administration of all aspects of the assessment was provided to the assistant psychologists by the author and a consultant in community paediatric epidemiology. The aims of the training were threefold:

a) to reduce to a minimum inter-observer variation (reported below);

b) to enable the development of a smooth and continuous style of presentation of the tasks and activities in order to help prevent fatigue and boredom on the part of the children;

c) to allow the investigators to become familiar with the assessment protocol to the extent that due attention could be given not only to the collection of quantitative data but also to qualitative observations.

The author was responsible for the training relating to the cognitive and scholastic aspects of the assessment and the consultant epidemiologist for the training relating to the assessments of motor functioning and neurological status. A videotape was produced to illustrate the administration of the QNST and a commercially available videotape was obtained which illustrated the administration of the Movement ABC. The BAS was taught by direct instruction by the author. A number of local schools not involved in the study agreed to allow access for the purpose of piloting the study.

4.2.7.1 Interobserver variation

Inter observer variation was found to exist in the data, with the children seen by one psychologist performing less well on average in five out of seven subscales of the British Ability Scales. The other two psychologists reported IQs for the comparison group which approximated the test norms. Potential confounding factors such as social class and parental educational qualifications were investigated in an attempt to explain the variation. The children seen by this psychologist were found to have significantly fewer parents who had received further education than those children seen by the other psychologists (19% *vs* 29%). While correcting for this confounding factor did not remove the interobserver effect, it was possible that the cognitive deficits seen by this psychologist were not solely attributable to observer bias. It would have been incorrect, therefore, to standardise the data to remove the effect of this observer. Instead, the original mean T-scores and IQs are reported. In consequence, the abilities of some children may be underestimated. However, interobserver variation was constant for both index and comparison groups, so the difference in abilities between the groups are unaffected by any observer bias which exists.

The tests of motor functioning (Movement ABC) and neurological status (QNST) were also investigated for evidence of interobserver bias. While there was no association between examiner and scores on the Movement ABC test, another of the psychologists appeared to have significantly fewer children obtaining high or suspicious scores on the QNST. Consequently the total number of children identified as having a neurological basis for learning disabilities may be underestimated. Nevertheless, as with the BAS , observer bias was found to be constant for both the index and comparison children.

4.2.8 Arrangement of school visit

The arrangements for school visits were organised by the study co-ordinator. As the psychologists were blind to the birthweight status of the children a decision was taken that the first approach to the school following receipt of parental consent forms should be by the study administrator. The study administrator advised the headteacher that the birthweight status of the triad of children should not be disclosed to the visiting psychologist.

(The data collected by the research nurses on their school visits involved taking measurements of growth, eyesight and hearing, blood pressure and lung function. The results of this part of the study are reported on separately, e.g. McLeod, Ross, Mitchell, Tay, Hunter, Hall, Paton & Mutch, 1996).

4.2.9 Characteristics of testing environment within the schools

Headteachers were requested to make available an area within their schools such as a visiting services or medical room for the purpose of assessing the children. The testing situation was always identical for any given triad and as similar as possible between schools.

Children were assessed without the distraction of other children or adults in the vicinity. The cognitive, educational, fine motor and neurological aspects of the assessment were carried out on a table top while the gross motor and balancing activities were carried out on an area of floor measuring not less than 10 feet by four feet. Occasionally, when the room allocated was insufficiently large, the gross motor activities had to be performed in a corridor or gymnasium.

All materials and accessories necessary to enable the children to record their responses were provided by the visiting psychologist.

4.2.10 Administration of the tests

The administration of the BAS, Movement ABC and the QNST were exactly as described in the manuals accompanying each of the tests. Recording booklets were devised for each of the tests including the instructions for administration.

4.2.11 Coding of the data

Data collected from administration of the BAS, Movement ABC and QNST were in the form of alphanumeric strings that did not require further coding prior to key-punching. The questionnaires received from the parents and teachers had to be coded into alphanumeric format prior to key-punching. Two coding forms were developed specifically for this purpose (appendix ??).

4.2.12 Data entry

The alphanumeric strings were typed into a word processing programme, Word 5.5 (Microsoft Corporation, 1990). A double-entry system was adopted whereby each string was key-punched twice. The strings were checked against one another using the 'glossary' and 'search' facilities. Where unequal strings were identified errors were located by reference to the original record forms. Once both strings were shown to be equal, one of the strings was deleted. The corrected strings were saved as ASCII files.

4.2.13 Statistical analysis

The complete data sets for each of the tests were read into a statistics programme, SPSS for Windows (Norusis/SPSS, 1993). The ASCII files were translated into SPSS data files for analysis.

Data from the four-year follow-up of the LBW children was retrieved from the Glasgow University mainframe, converted to ASCII format and saved as SPSS data files. Data relating to those children with birthweights >=1500g <1750g were removed from the data set prior to linking with the eight-year data sets. Thus, only data on VLBW (<1500g) children from the four-year follow-up was retained. Initial statistical analysis including cleaning of the data sets, investigation of the existence of inter observer variation and basic comparisons were undertaken by the study group statistician.

Subsequent data analysis was undertaken by the author using Statistica for Windows 95 Release 5.1 (Statsoft, 1984-1997.) The SPSS data files were saved in SPSS.POR (portable) format and converted to Statistica data files. All analyses previously undertaken by the study group statistician, with the exception of the investigation into interobserver variation, were repeated to confirm that datasets had not been corrupted in the translation from SPSS to Statistica.

The results of the data analyses are presented in the following chapter. The first set of analyses provides a detailed description of VLBW cohort at eight years of age and where possible the comparison group.

The second set of analyses involves a comparison of the VLBW cohort with their heavier birthweight classroom peers in relation to cognitive functioning and scholastic attainment. This includes the strand of investigation into the use of concurrent norms derived from the control group as opposed to published norms for the tests and the existence of specific learning difficulties (dyslexia).

The third set of analyses involves a comparison of the index and comparison groups in terms of motor functioning and neurological status.

Other strands of investigation include differences in outcome between children who were small for gestational and those who were appropriate birthweight for gestational age, gender differences and motor competence as a possible confounding factor in assessment of visual cognitive functioning.

Chapter Five

Low Birthweight Research – Results

Section 1 Illustrative Characterisation of the Index Group and, where possible, the Comparison Group

5.1.1 Description of index and comparison groups

This chapter starts with a comprehensive description of the characteristics of the index group. As later analyses will investigate differences in outcome by small for gestational age/appropriate for gestational age status, by gender and by birthweight groupings, the cohort will be described not only as a single group but also by gestational age, SGA/AGA status, gender and birthweight grouping (<1000g and 1000-1499g).

5.1.1.1 Birthweight distributions

The mean birthweight and birthweight distribution of the index group (all children; female; male) are presented below. (The histograms for VLBW females and males are presented in Appendix 1.)

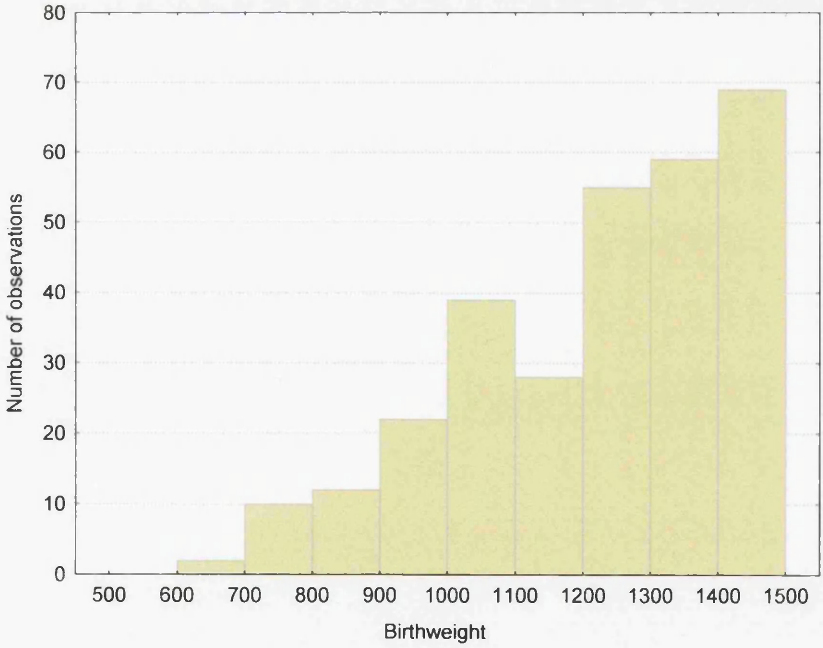

Figure 5.1.1.1 Birthweight distribution for index children (all<1500g)

TABLE 5.1.1.1

Mean birthweights of index children

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (all <1500g)	297*	1227g	650g	1495g	200g
Index group (female)	151	1205g	650g	1495g	206g
Index group (male)	146	1250g	770g	1490g	191g

**Missing data on three cases (two female, one male)*

5.1.1.2 Gender differences in mean birthweights

Difference in mean birthweights for female and male index children was investigated (t-test for independent samples). The mean birthweight for the females was 1205g and for the boys 1250g. This difference was significant ($p<0.05$) and most probably arises because males tend to be heavier than girls of the same gestational age. (It may also reflect the higher rate of neonatal mortality for boys born at the limits of viability.) Reference to the birthweight distributions for index females and index males (Appendix 1) demonstrates the greater proportion of females born at lower birthweights (see also table 5.1.2.1 below.) The box and whisker plot shows a minimum birthweight value for females at <700g but nearer to 800g for males (figure 5.1.1.2).

Figure 5.1.1.2 Box and whisker plot of birthweight by gender for index children (all <1500g)

TABLE 5.1.1.2

Difference in mean birthweights of female and male index children

	N	Mean	SD	t-value	df	P	Levene F (1, df)	df	P Levene
Index group (female)	151	1205g	206g	-1.97	295	0.49	1.82	295	0.18
Index group (male)	146	1250g	191g						

5.1.1.3 Birthweight distributions by birthweight groupings

The birthweight distributions of the index group by birthweight groupings (<1000g and 1000-1499g) are presented below.

5.1.1.3.1 Mean birthweights and birthweight distributions for the <1000g group

The mean birthweight for <1000g group was 870g. The birthweight of the smallest infant, a girl, was 650g. The smallest boy in this birthweight group weighed 770g. Of the 44 valid cases in this group there were eight more females than males.

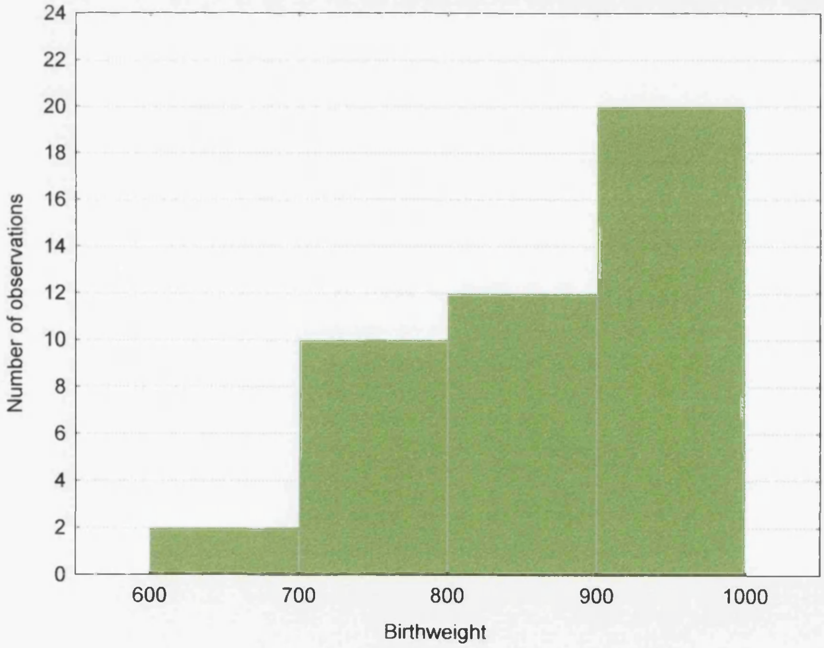

Figure 5.1.1.3.1 Birthweight distribution for index children (all<1000g)

TABLE 5.1.1.3.1

Mean birthweights of index children (<1000g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (all <1000g)	44*	870g	650g	992g	85g
Index group (female)	26	868g	650g	980g	92g
Index group (male)	18	872g	770g	992g	77g

**Missing data on one case (one female)*

5.1.1.3.2 Gender differences in mean birthweights for index children (<1000g)

Difference in mean birthweights of ELBW female and ELBW male children was investigated (t-test for independent samples). The mean birthweight for ELBW females was 868g and for ELBW males 872g. This difference was not statistically significant.

TABLE 5.1.1.3.2

Difference in mean birthweights of female and male index children <1000g

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group (female)	26	868g	92g	-0.18	42	0.86	0.19	42	0.66
Index group (male)	18	872g	77g						

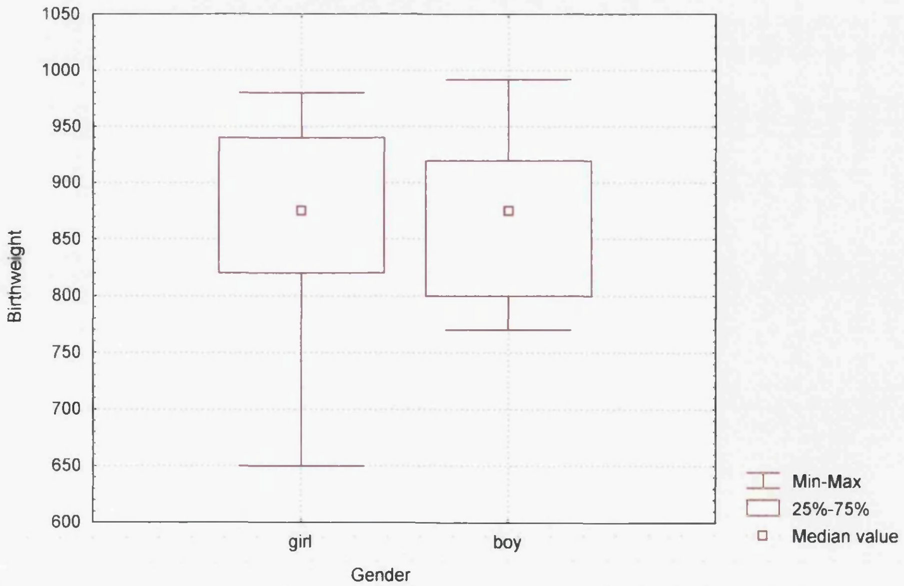

Figure 5.1.1.3.2 Box and whisker plot of birthweight by gender for index children <1000g

5.1.1.3.3 Mean birthweights and birthweight distributions for the 1000-1499g group

The mean birthweight for the 1000-1499g group was 1289g. The number of females and males in this birthweight grouping was very similar – of 253 valid cases there were just three more males than females.

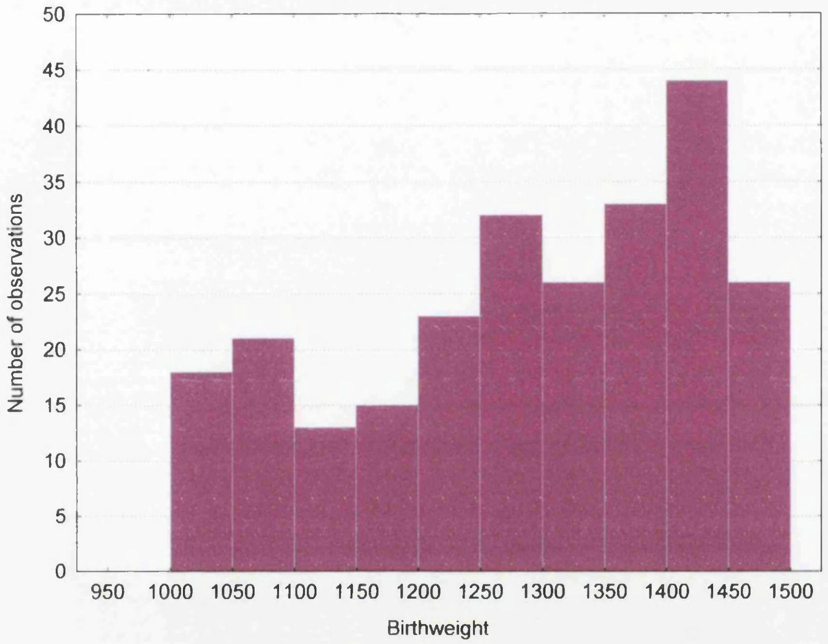

Figure 5.1.1.3.3 Birthweight distribution for index children (all 1000-1499g)

TABLE 5.1.1.3.3

Mean birthweights of index children (1000-1499g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (1000-1499g)	253*	1289g	1000g	1495g	140g
Index group (female)	125	1275g	1000g	1495g	144g
Index group (male)	128	1303g	1003g	1490g	134g

**Missing data on two cases (one female and one male)*

5.1.1.3.4 Gender differences in mean birthweights for index children (1000-1499g)

Difference in mean birthweights for female and male index children 1000-1499g was investigated (t-test for independent samples). The mean birthweight for females in this birthweight group was 1275g and for males 1303g. The difference was not significant (p>0.05).

TABLE 5.1.1.3.4

Difference in mean birthweights of female and male index children 1000-1499g

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group (female)	125	1275g	144g	-1.63	251	0.10	2.68	251	0.10
Index group (male)	128	1303g	134g						

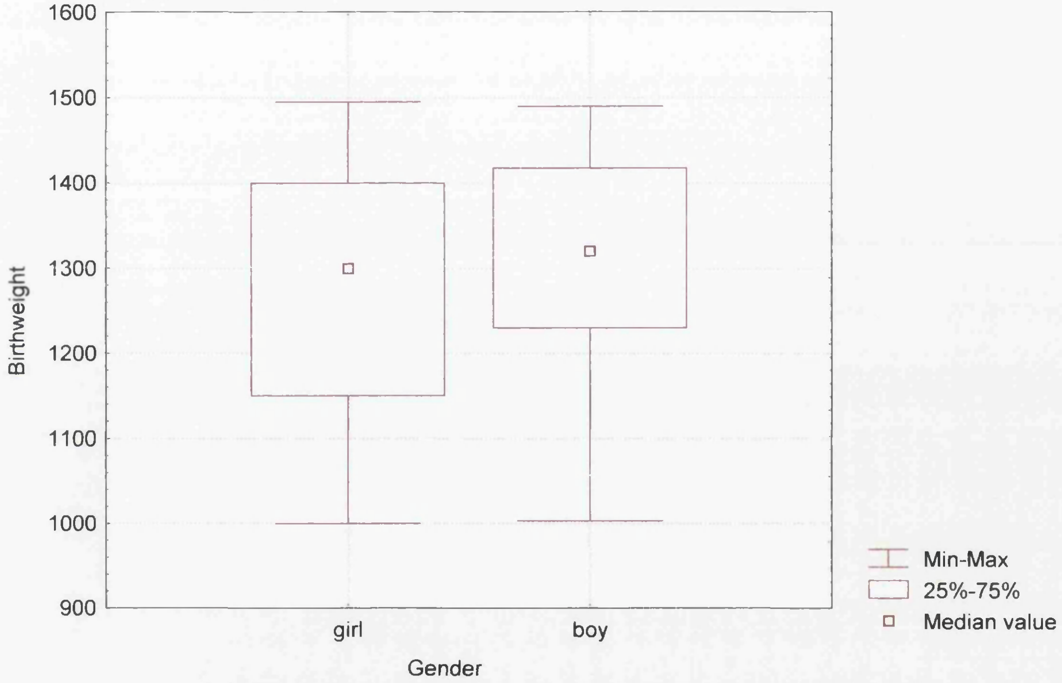

Figure 5.1.1.3.4 *Box and whisker plot of birthweight by gender for index children 1000-1499g*

5.1.2 Gestational age distributions

The mean gestational age and gestational age distribution of the index group (all children; female; male) are presented below.

TABLE 5.1.2.1
Mean gestational age of index children (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (all <1500g)	297	30.3 weeks	24.0	40.0	2.8 weeks
Index group (female)	151	30.2 weeks	24.0	39.0	2.6 weeks
Index group (male)	146	30.3 weeks	24.0	40.0	3.0 weeks

**Missing data on three cases (2 female and one male)*

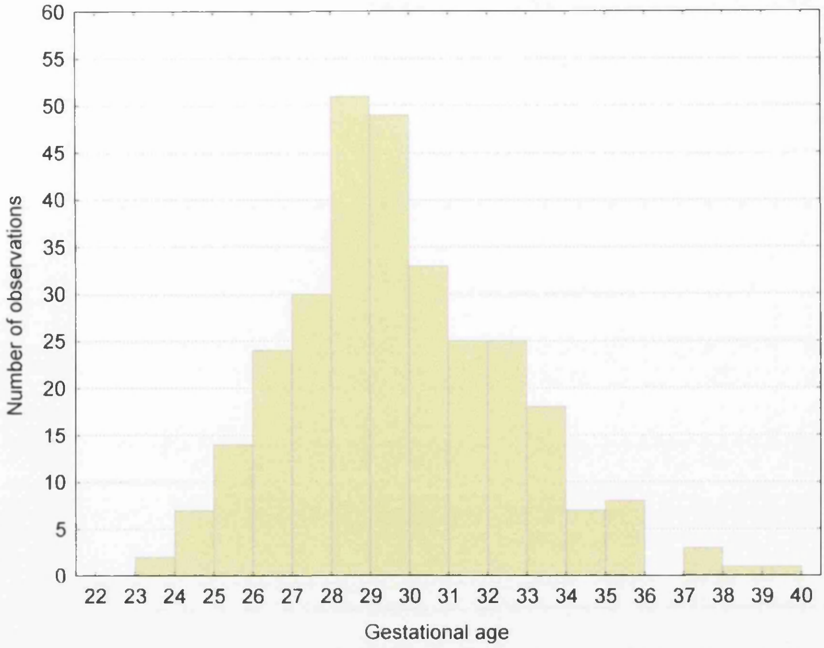

Figure 5.1.2.1.1 Gestational age (weeks) distribution for index children (all<1500g)

5.1.2.1 Gender differences in mean gestational ages

Difference in mean gestational ages for female and male index children was investigated (t-test for independent samples). The mean gestational age for the females was 30.2 weeks and for the boys 30.3 weeks. This difference was not significant (p>0.05).

TABLE 5.1.2.1

Difference in mean gestational ages of female and male index children

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group (female)	151	30.2 weeks	2.6	-0.15	295	0.88	1.04	295	0.31
Index group (male)	146	30.3 weeks	3.0						

Figure 5.1.2.1.2 *Box and whisker plot of gestational age by gender for index children (all <1500g)*

5.1.2.2 Gestational age distributions by birthweight groupings

The birthweight distributions of the index group by birthweight groupings (<1000g and 1000-1499g) are presented below.

5.1.2.2.1 Mean gestational ages and gestational age distributions for the <1000g group

Of the 44 index children who were <1000g at birth all were born at 33 weeks or earlier; for those for whom data were available the mean gestational age was 27 weeks.

TABLE 5.1.2.2.1
Mean gestational age of index children (<1000g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (<1000g)	44*	27 weeks	24	33	2.2
Index group (female)	26	28 weeks	24	33	2.4
Index group (male)	18	26 weeks	24	30	1.4

**Missing data on one case (one female)*

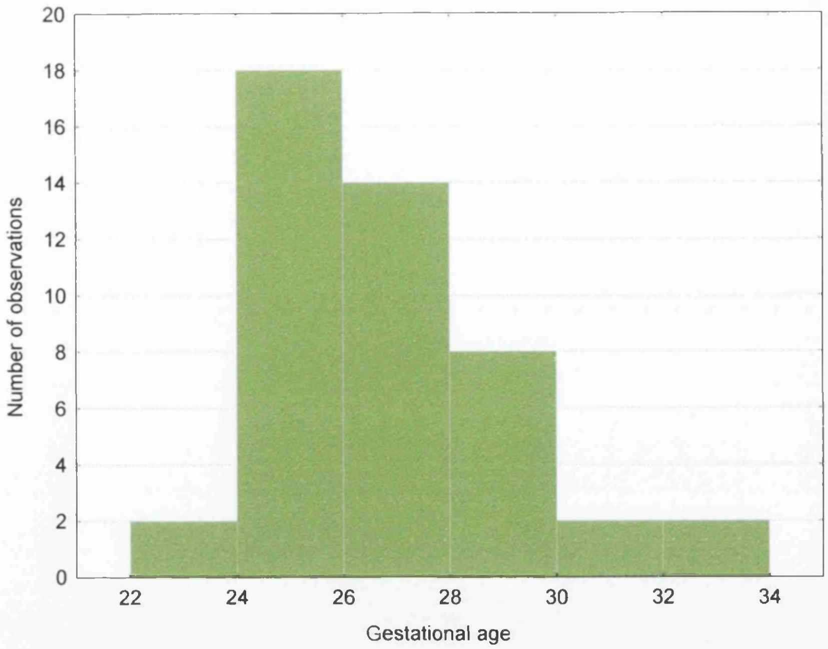

Figure 5.1.2.2.1 Gestational age (weeks) distribution for index children (all< 1000g)

5.1.2.2.2 Gender differences in mean gestational ages

The mean gestational age for the females was 27.9 weeks and for the boys 26.3 weeks. This difference was significant ($p<0.01$). Levene's test for homogeneity of variances was, however, significant ($p<0.05$). This means that homogeneity of variance cannot be assumed and this, in turn, means that it is unsafe to accept the significance of the difference between mean scores. Where number exceed 30, even where the test of homogeneity of variance is significant, there can be a cautious acceptance of the significance of the difference between means. In this analysis, however, the number of female and male children was 26 and 18 respectively. Thus the significance of the difference between the mean scores must be regarded as unsafe.

This demonstrates again that in this population of infants less than 1000g the boys of 26.3 weeks gestation are heavier than girls of the same gestational age.

TABLE 5.1.2.2.2

Difference in mean gestational ages of female and male index children (<1000g)

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group (female)	26	27.9 weeks	2.4	2.60	42	0.01	4.18	42	0.047
Index group (male)	18	26.3 weeks	1.4						

Figure 5.1.2.2.2 Box and whisker plot of gestational age by gender for index children (<1000g)

5.1.2.2.3 Mean gestational ages and gestational age distributions for the 1000-1499g group

The mean gestational age for all children in this birthweight grouping was 31 weeks. The shortest gestational age was 26 weeks for both males and females, the maximum gestational age was 39 weeks for females and 40 weeks for males.

TABLE 5.1.2.2.3

Mean gestational age of index children (1000-1499g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (1000-1499g)	253*	31 weeks	26	40	2.6 weeks
Index group (female)	125	31 weeks	26	39	2.4 weeks
Index group (male)	128	31 weeks	26	40	2.7 weeks

**Missing data on two cases (one female and one male)*

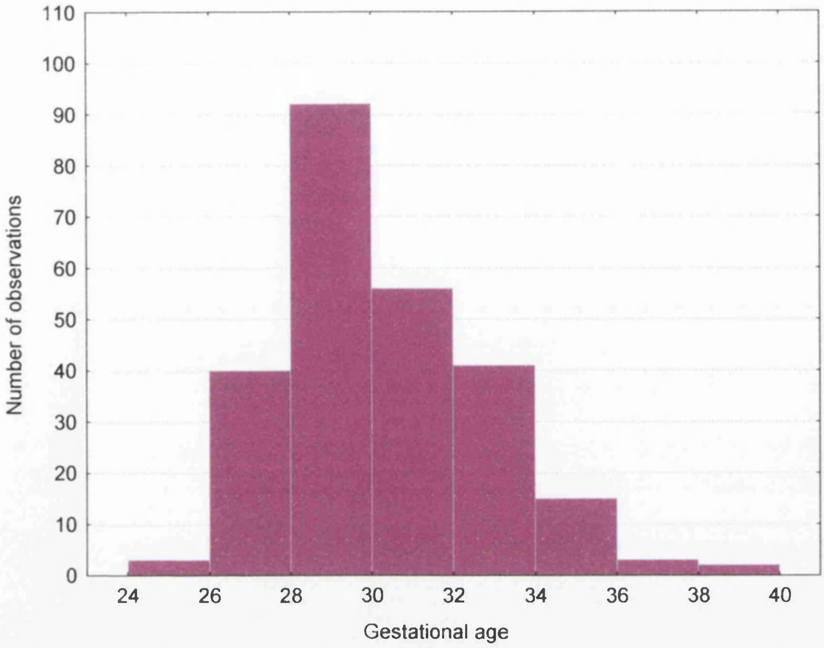

Figure 5.1.2.2.3 Gestational age (weeks) distribution for index children (all 1000-1499g)

5.1.2.2.4 Gender differences in mean gestational ages

Difference in mean gestational ages for female and male index children (1000-1499g) was investigated (t-test for independent samples). The mean gestational age for both females and males was virtually the same and the test for significance of difference between the means was not significant.

TABLE 5.1.2.2.4

Difference in mean gestational ages of female and male index children (1000-1499g)

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group (female)	125	30.7 weeks	2.4	-.41	251	0.68	0.78	251	0.38
Index group (male)	128	30.9 weeks	2.7						

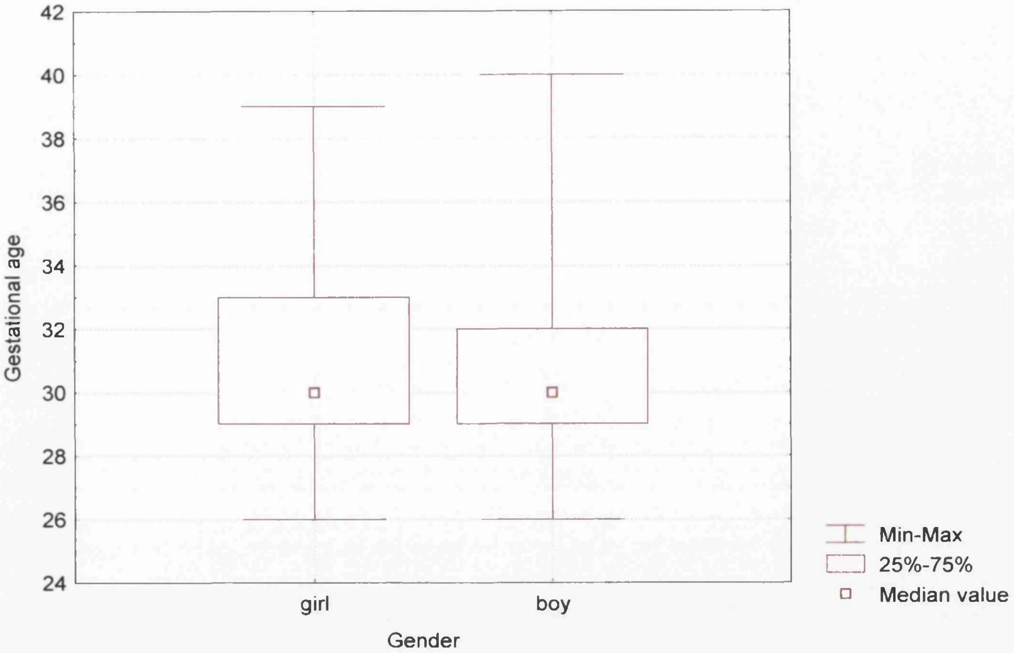

Figure 5.1.2.2.4 *Box and whisker plot of gestational age by gender for index children (1000-1499g)*

5.1.3 Age distributions

5.1.3.1 Age distribution for index group at time of assessment

The mean age and distribution of age at time of assessment for the index group (all children; female; male) are presented below. All of the children were assessed within the course of one school year. The mean ages of the index and comparison groups at time of assessment were between 8.7 and 8.8 years. The distributions for age at time of assessment by gender for the index group are presented in Appendix 1

TABLE 5.1.3.1

Mean age at time of assessment of index children

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (all <1500g)	300	8.82 years	8.10	9.80	0.32 years
Index group (female)	153	8.80 years	8.10	9.80	0.31 years
Index group (male)	147	8.83 years	8.10	9.50	0.33 years

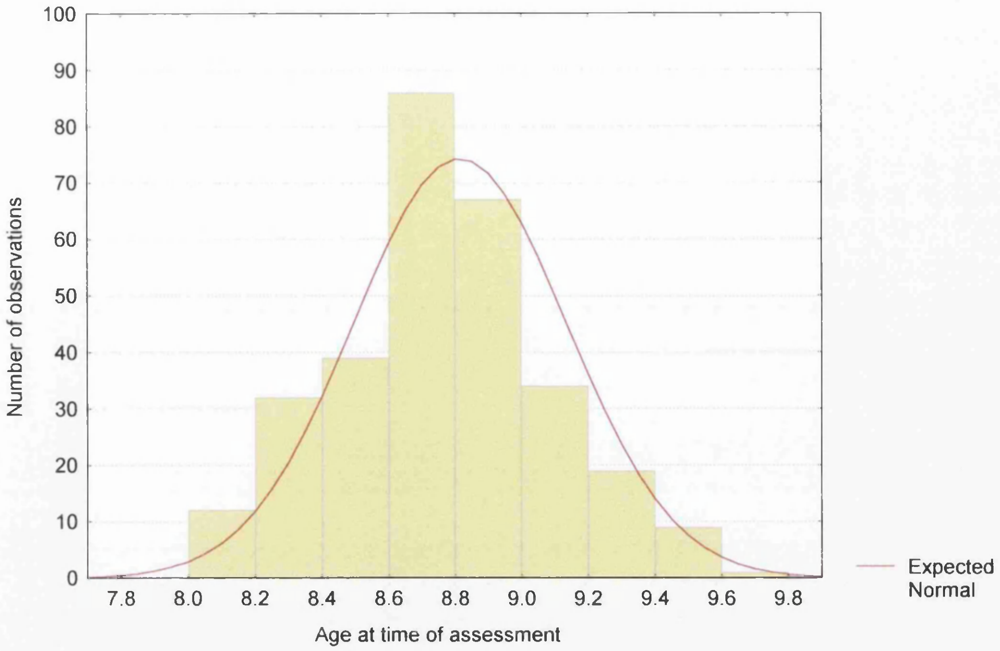

Figure 5.1.3.1 Age distribution for index children at time of assessment (all<1500g)

5.1.3.2 Age distribution for comparison group at time of assessment

The mean age and distribution of age at time of assessment for the comparison group (all children; female; male) is presented below. A small number of comparison children who were a year or more older or younger than the mean age of the index group were included (refer to distribution of comparison children below). This came about as a result of the difficulty in identifying matched comparison children in small rural schools. In such schools it is common for composite classes to be taught – a composite class might cover anything up to all seven stages of primary education. Occasionally, where the school roll was small, it turned out that there were no comparison children in the same year group as the index child and the child nearest in date of birth was in the year above or the year below – but still being taught in the same teaching environment. On these few occasions these older or younger children were assessed for the purpose of comparison in preference to not having any control.

The distributions of age at time of assessment by gender for the comparison group are presented in Appendix 1.

TABLE 5.1.3.2

Mean age at time of assessment of comparison children

	N	Mean	Minimum	Maximum	Standard Deviation
Comparison group (all)	590	8.77 years	6.50	10.60	0.38 years
Comparison group (female)	298	8.75 years	6.50	9.60	0.36 years
Comparison group (male)	292	8.78 years	7.00	10.60	0.40 years

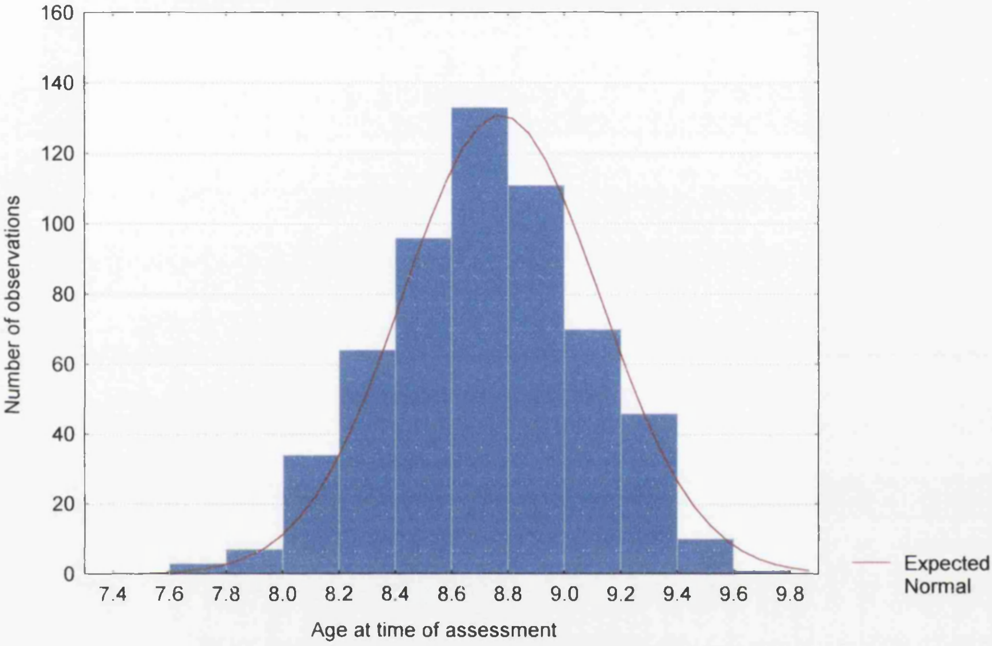

Figure 5.1.3.2 *Age distribution for comparison children at time of assessment*

5.1.4 Small for gestational age status of the index and comparison groups

The small for gestational age (SGA) status versus appropriate birthweight for gestation age (AGA) status is presented below for both index and comparison groups.

TABLE 5.1.4

SGA status of index children (excluding those in special education) and comparison children

	SGA	AGA	Missing data on SGA status	Total
Index group (all <1500g)	92	205	3	300
Comparison group	62	429	99	590

5.1.5 Socio demographic factors

The social and demographic factors, obtained by parental questionnaire, are summarised below.

TABLE 5.1.5

Socio demographic characteristics of the index and comparison groups

	VLBW	Comparison
Age at assessment (years)	8.8 (0.3)	8.8 (0.4)
Maternal age (years)	35.2 (6.1)	36.1 (5.8)
Paternal age (years)	37.4 (7.8)	37.2 (5.8)
Parental social class		
I,II and III NM	65 (22)	166 (28)
III M	76 (25)	170 (29)
IV and V	38 (13)	95 (16)
Unknown	121 (40)	159 (27)*
Parental educational qualifications		
None	74 (25)	124 (21)
O grades/apprenticeship	106 (35)	244 (42)
Higher education	56 (19)	132 (22)
Unknown	64 (21)	90 (15)
Single parent family	54 (18)	70 (12)*
Father unemployed > 1 year	42 (14)	51 (9)*

*χ^2 $p<0.05$. *Numbers in first three rows are Mean (SD); numbers in rest of table are N (%).*

The index and comparison groups did not differ in respect of their father's or mother's age at the time of the assessment. The occupation of more of the index children's parents was unknown; this was partly a reflection of the higher proportion of single non working mothers in this group. The index group appeared to have fewer parents in non manual occupations, but the difference in social class distributions was not significant. There were only modest differences in the distribution of parental educational levels between the index group and comparison group and none was statistically significant. More of the VLBW children were currently living in single parent households and more of this group also had fathers who had been unemployed for more than one year.

Section 2 Assessment of Cognitive Functioning and Educational Attainment

5.2.1 Cognitive functioning – Index children versus comparison children

The hypotheses in this study were originally framed in terms of differences between VLBW (all <1500g) and comparison children. The results, however, have never hitherto been reported in this manner. The first report of the results was organised in terms of case-control differences according to birthweight groupings (Hall et al., 1995). This was partly as a result of increasing clinical interest in the longer term outcomes of ELBW infants and also to allow a more ready comparison with other studies reporting upon their cohorts in this way (e.g. Pharoah et al., 1994; Marlow et al., 1993). There are, however, many other studies that report upon VLBW cohorts without organising the children into birthweight groupings. To test the hypotheses as they were originally framed and to enable a more ready comparison with those studies that have reported upon VLBW cohorts (all <1500g), the analyses in this section compare the VLBW group as a whole with the comparison group.

5.2.1.1 Distribution of IQ (British Ability Scales)

The mean general IQ for the VLBW group was 93.2 (SD 13.3) and for the comparison group was 101.3 (SD 12.4). The VLBW group had, on average, a significantly lower level of general cognitive functioning.

A difference was found to exist between the mean and standard deviation for the comparison group and published test norms. Although the difference was not statistically significant it does cast some doubt as to whether the published norms can be regarded as representative of Scottish children of eight to nine years of age. The IQ distribution below is, therefore, based upon concurrent norms derived from the matched comparison group. (This issue is discussed in detail in Chapter 6.)

Children in the VLBW group are five times more likely to have general IQs more than 2 SD below the mean than children in the comparison group. At the upper end of the range, only 5% of the VLBW group scored more than 1 SD above the mean as compared with 17% of the comparison group.

TABLE 5.2.1.1

Distribution of IQ – index children (<1500g) and comparison children (using comparison group norms)

	Index Group N=299^x N (%)	Comparison Group N=590 N (%)
Mean IQ (SD)	93.2 (13.3)	101.3 (12.4)*
Number of children with IQ: (%)		
≥ 2 SD below mean - for comparison group	32 (11)	11 (2)**
>1 – <2 SD below mean	84 (28)	77 (13)**
1 SD below to 1 SD above the mean	168 (56)	404 (68)
>1 SD above mean	15 (5)	98 (17)**

*p<0.0001 (refer to table 5.2.1.2 below)
**χ^2 p<0.0001
^{x}One index child unable to complete all the subscales because of profound deafness.

The hypothesis that the index children would gain significantly lower scores than the comparison group was investigated by t-test for independent samples. The difference between mean IQ of 93.2 (SD 13.3) for the index group and 101.3 (SD 12.4) for the comparison group was statistically significant.

TABLE 5.2.1.2
Difference in mean IQs – index (<1500g) versus comparison children

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group	299	93.2	13.3	-8.94	887	0.0001	1.26	887	0.26
Comparison group	590	101.3	12.4						

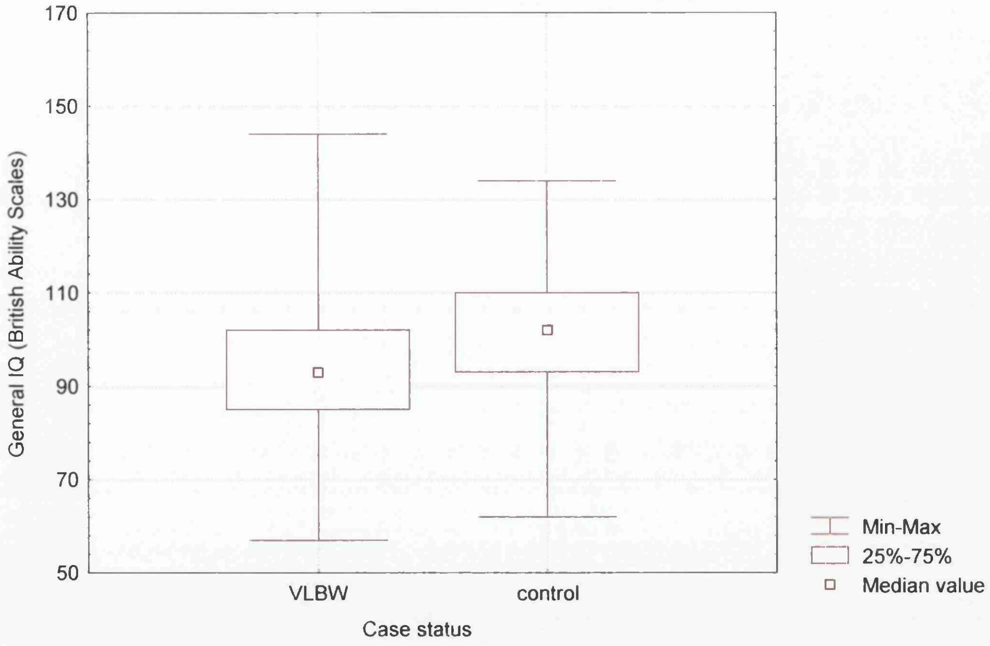

Figure 5.2.1 *Box and whisker plot for general IQ by case status*

5.2.2 Comparison of scores on cognitive subskills

An analysis of the performance of the index and comparison groups on the subtests of the BAS is presented below. In the BAS, general IQ is computed from a composite of eight (and not less than seven) subtests. (A short form IQ can also be computed from the scores on four subtests.) In the present study, because of the extensive nature of the assessment protocol, seven rather than eight subtests were administered, that is, the minimum number required to compute a full scale general IQ. This was partly due to reasons of time and partly out of consideration for the demands being placed upon the children. The one subtest that was omitted was Block Design – Level. This differs from the Block Design – Power test (which was administered) only in terms of the time allowed to construct a given pattern. Therefore, there was no cognitive subskill that forms a part of the general IQ composite of the BAS that was not assessed. Both tests of Block Design are assessing spatial visualisation – but one under a more stringent time demand.

Of the seven subskills assessed the index group gained significantly lower scores than the comparison group on all with the exception of Recall of Digits – a test of short term auditory sequential memory. The average score of the index group on this subtest was only marginally lower than that of the comparison group and it was not significant. (The details of the tests of significance are presented in Appendix 2.)

Both the index and comparison group achieved relatively low scores on the Word Definitions subtest – although the mean score of the comparison group was significantly higher than that of the index group. The Word Definitions subtest assesses retrieval and application of knowledge from long term memory. On the Recall of Designs subtest, on other hand, both groups scored relatively strongly. Again, however, the mean score of the comparison group was significantly higher than that of the index group. The Recall of Designs subtest assesses short term visual memory.

TABLE 5.2.2
Mean T scores for cognitive sub-skills (British Ability Scales) - index children and comparison children

	VLBW Group		*Comparison Group*	
	Mean	*(SD)*	*Mean*	*(SD)*
Ability Scales				
Similarities	48.4	(9.7)	50.9	(9.7)*
Recall of Digits	48.2	(10.4)	49.0	(9.1)
Speed of Information Processing	47.3	(10.4)	52.2	(10.1)**
Word Definitions	39.6	(9.6)	43.1	(9.4)**
Matrices	45.9	(9.5)	50.0	(8.9)**
Recall of Designs	50.8	(10.3)	55.5	(9.0)**
Block Design	47.3	(10.9)	53.6	(9.8)**

*p<0.001
**p<0.0001

5.2.3 Comparison of general IQ, verbal IQ and visual IQ composite scores

In addition to generating a general IQ composite score, based upon all of the cognitive subtest scores, it is also possible to compute verbal and visual IQ composite scores. The verbal IQ composite comprises the Similarities, Recall of Digits, Speed of Information processing and Word Definitions scales. The visual IQ composite comprises the Matrices, Recall of Designs and Block Design scales.

While considering discrete areas of cognitive functioning is a more detailed and informative way of investigating differences between VLBW and comparison children it is, nevertheless, valuable to generate composite scores to allow comparison with other studies. The favoured test of cognitive functioning in earlier studies (particularly in the US) of VLBW and very premature children is the WISC-R – the results of which are reported in terms of full scale IQ, verbal IQ and visual/performance IQ.

It was predicted that the VLBW children would achieve lower scores than the comparison group in terms of general IQ, verbal IQ and visual IQ. The results below demonstrate that this prediction was upheld. (The details of the tests of significance are presented in Appendix 2.)

TABLE 5.2.3
Mean general, verbal and visual IQs(British Ability Scales) - index children and comparison children

	VLBW Group		*Comparison Group*	
	Mean	*(SD)*	*Mean*	*(SD)*
General IQ	93.2	(13.3)	101.3	(12.4)*
Verbal IQ	91.3	(13.9)	97.4	(13.5)*
Visual IQ	95.7	(17.1)	106.4	(15.2)*

*p<0.0001

5.2.4 Comparison of scores of educational attainment

One of the central concerns of the present study relates to the school progress of Scottish VLBW children. As children progress through their primary school careers the most important skills they acquire are, arguably, those of literacy and numeracy. It has been postulated that, as the demands of school education increase, the difficulties experienced by VLBW will become more apparent. Neurological impairments that may be subtle and unobtrusive in the pre school years may become manifest as school failure later on.

To investigate this area of development two scholastic attainment test were incorporated into the assessment protocol, namely, Word Reading and Basic Number Skills (representing the two tests of attainment included in the BAS). It was predicted that mean reading and number scores achieved by the VLBW group would be significantly lower than for the comparison group. While this prediction was upheld, as the table below demonstrates, the mean reading score for the index group held up well – falling just below the mean for the published norms of the BAS. (Details of the tests of significance between mean scores are presented in Appendix 2. The Chi square statistic was used to test the significance of the difference in the proportions of index and comparison children falling below the 10th percentile.)

TABLE 5.2.4

Mean scores and numbers of children functioning below 10th percentile (for the comparison group) on school attainment tasks(British Ability Scales) - index children and comparison children

	VLBW Group		*Comparison Group*		*95% CI*
Word reading	49.6	(SD 11.2)	52.7	(SD 10.9)*	
N below 10th percentile	62	(20.7%)	67	(11.4%)**	
Number skills	44.3	(SD 10.1)	49.1	(SD 10.0)*	
N below 10th percentile	75	(25.0%)	63	(10.7%)***	

*$p<0.0001$

**χ^2 $p<0.005$

***χ^2 $p<0.0001$

5.2.5 The relationship between cognitive and scholastic measures

There was a strong relationship between general IQ (BAS) and scores of both reading and number. The correlations were equally strong for the index and comparison groups. The correlations using Pearson Product Moment Coefficient are presented in Table 5.2.5.1 (index children) and Table 5.2.5.2 (comparison children) below.

TABLE 5.2.5.1

Relationship between general IQ and measures of scholastic attainment – index children (Pearson Product Moment Correlation)

Case		General IQ	Reading	Number
Index Children	General IQ		0.54 p<0.05	0.56 p<0.05
	Reading	0.54 p<0.05		0.64 p<0.05
	Number	0.56 p<0.05	0.64 p<0.05	

TABLE 5.2.5.2

Relationship between general IQ and measures of scholastic attainment – comparison children (Pearson Product Moment Correlation)

Case		General IQ	Reading	Number
Comparison children	General IQ		0.52 $p<0.05$	0.54 $p<0.05$
	Reading	0.52 $p<0.05$		0.50 $p<0.05$
	Number	0.54 $p<0.05$	0.50 $p<0.05$	

5.2.5.1 The influence of IQ on poor performance on measures of scholastic attainment

5.2.5.1.1 Number skills

It is plausible that the differences on measures of educational attainment between the index and comparison groups could be accounted for more in terms of differences in IQ than birthweight differences. To investigate this possibility reading and number scores for the index males and females and comparison males and females were compared while controlling for general IQ (ANCOVA). The first table demonstrates the effects of case and gender without entering general IQ in the model as a covariate. The p-level for case is significant with a high degree of confidence.

Table 5.2.5.1.1.1
Differences between index and comparison females and males on basic number skills without controlling for general IQ

	MS Effect	F	p-level
Case	4607.5	45.633	0.000
Gender	156.0	1.545	0.214
Case x gender	295.4	2.925	0.088

Table 5.2.5.1.1.2 below and demonstrates that, after entering general IQ in the ANCOVA model, the difference in number scores by case is still significant – but with a greatly reduced p-level. Interestingly gender is now having more of an effect – although not significantly so. (The investigation of gender differences is presented in detail below.)

Table 5.2.5.1.1.2

Differences between index and comparison females and males on basic number skills controlling for general IQ (ANCOVA)

	MS Effect	F	p-level
Case	297.15	4.214	0.040
Gender	241.54	3.425	0.065
Case x gender	164.20	2.329	0.127

5.2.5.1.2 Reading skills

The investigation was repeated in relation to reading scores for the index males and females and comparison males and females. Again the first table demonstrates the effects of case and gender without entering general IQ in the model as a covariate. Once again the p-level for case is significant.

Table 5.2.5.1.2.1

Differences between index and comparison females and males on reading skills without controlling for general IQ

	MS Effect	F	p-level
Case	1880.7	15.492	0.000
Gender	3.1	0.025	0.874
Case x gender	6.1	0.050	0.823

The table below demonstrates that, after controlling for general IQ, the effect of case difference on reading skills is no longer significant. The issue of the relationship between reading skills and general intelligence is developed in Chapter 6.

Table 5.2.5.1.2.2

Differences between index and comparison females and males on reading skills controlling for general IQ (ANCOVA)

	MS Effect	F	p-level
Case	82.221	0.943	0.332
Gender	2.302	0.026	0.871
Case x gender	4.665	0.054	0.817

Section 3 Comparison of Children who were Small for Gestational Age (SGA) and Children who were of appropriate birthweight for Gestational Age (AGA).

5.3.1 General cognitive ability SGA versus AGA

It was predicted that those index children who were small for gestational age would, on average, achieve a lower mean IQ score than those index children who were of appropriate size for gestational age. On the assumption that being small for gestational age is disadvantageous as far as cognitive outcome is concerned, it was also predicted that comparison children who were SGA would also achieve, on average, a lower mean IQ score than their AGA counterparts.

TABLE 5.3.1.1
Distribution of IQ by SGA-AGA status – index children and comparison children (using comparison group norms)

	SGA index (N=92) N (%)	AGA index (N=207)^x N (%)	SGA control (N=62) N (%)	AGA control (N=429) N (%)
Mean IQ (SD)	94.1 (11.8)	92.8 (13.9)	98.5 (12.9)	103.0 (12.3)*
Number of children with IQ: (%)				
≥ 2 SD below mean - for comparison group	7 (8)	25 (12)	1 (2)	7 (2)
>1 – <2 SD below mean	23 (25)	61 (29)	15 (24)	38 (9)**
1 SD below to 1 SD above the mean	58 (63)	111 (54)	39 (63)	298 (69)
>1 SD above mean	4 (4)	10 (5)	7 (11)	86 (20)

*p<0.05

**χ^2 p<0.05

^{x}One AGA index child unable to complete all the subscales because of profound deafness.

The IQ distribution is based on concurrent norms derived from the comparison group. There is a considerable amount of missing data regarding the SGA/AGA status of the comparison group (99 missing cases). Nevertheless there are 491 comparison children for whom the SGA/AGA status is known. While it is the case that the comparison groups is matched for gender, age and classroom environment, because the study group is a total nationwide cohort the matched comparison group should be representative of Scottish eight – nine year old children in general.

The mean IQ for the SGA index group was 94.1 as compared with 92.8 for the AGA index group. While the difference between the mean scores was not significant (table 5.3.1.2), the direction of the difference was, in fact, opposite to that which had been predicted. The mean score for the SGA comparison group was 98.5 as compared with 103 for the AGA comparison group. The direction of the difference between the mean scores was as predicted and the extent of the difference was significant (table 5.3.1.2).

There were no significant differences between the SGA index children and the AGA index children in any of the IQ groupings in the distribution. As far as the comparison group is concerned, 24% of the SGA comparison children had IQ scores between 1SD and 2SD below the mean as compared with 9% of the AGA comparison children – this difference was significant (Chi square statistic). There were no significant differences in any of the other IQ groupings of the distribution.

TABLE 5.3.1.2

Differences in mean General IQ scores by SGA/AGA status and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		Mean=92.8	mean=103.0	mean=94.1	mean=98.5
AGA	VLBW	(1)		0.000	0.859	0.011
AGA	control	(2)	0.000		0.000	0.045
SGA	VLBW	(3)	0.859	0.000		0.150
SGA	control	(4)	0.011	0.045	0.150	

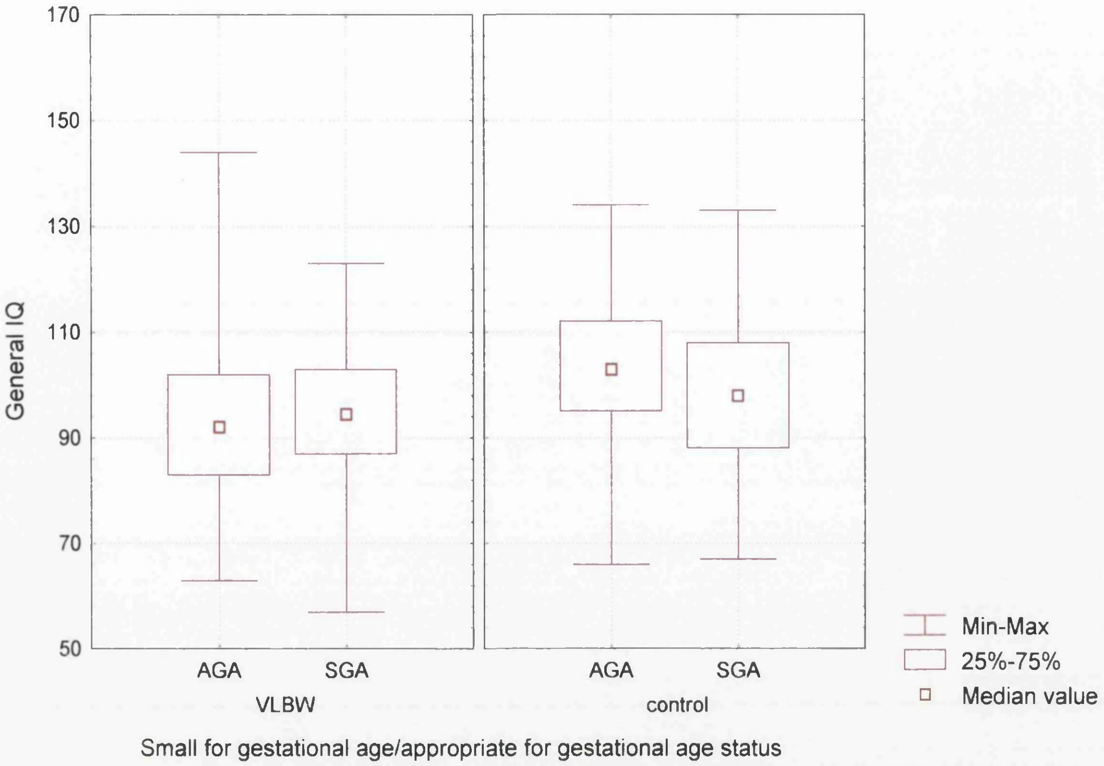

Figure 5.3.1 *Categorised box and whisker plot for general IQ by SGA/AGA and case status*

5.3.2 Comparison of scores on cognitive subskills by SGA/AGA status

The seven scales of the BAS were investigated for differences on the basis of SGA/AGA status. The mean scores (SD) for both the index and control groups were as follows:

TABLE 5.3.2

Mean cognitive sub skills score (SD) (British Ability Scales) by SGA/AGA status – index and comparison children

	VLBW SGA (N=92)	VLBW AGA (N=207)^x	Comparison SGA (N=62)	Comparison AGA (N=429)
Ability Scales				
Similarities	50.0 (10.0)	47.6 (9.5)	49.4 (10.2)	51.9 (9.6)
Recall of Digits	48.5 (10.2)	48.0 (10.5)	46.7 (9.4)	49.9 (8.9)
Speed of Information Processing	46.6 (9.6)	47.6 (10.7)	53.0 (11.1)	52.6 (9.9)
Word Definitions	40.5 (8.2)	39.2 (10.2)	41.3 (10.4)	44.6 (9.3)
Matrices	46.6 (9.3)	45.6 (9.5)	48.4 (8.6)	51.0 (8.8)
Recall of Designs	51.0 (9.4)	50.7 (10.7)	53.5 (7.9)	55.8 (8.9)
Block Design	47.5 (9.7)	47.3 (11.4)	52.7 (9.3)	54.2 (9.9)

^{x}One index child unable to complete all the subscales because of profound deafness.

On all of the scales of the BAS, with the exception of Speed of Information Processing, the SGA index group gained higher scores, on average, than the AGA index children. None of the differences, however, was statistically significant (refer to Appendix 3 for two way ANOVAs for all scales of the BAS and composite IQs).

With regard to the comparison children, the AGA group gained higher scores on all of the scales of the BAS with the exception of Speed of Information Processing. Again, however, none of the differences was statistically significant (refer to Appendix 3).

5.3.3 Comparison of verbal and visual composite IQ scores by SGA/AGA status

Composite scores for verbal IQ and visual IQ were computed from the appropriate scale scores of the BAS and compared by SGA/AGA status for both the index and comparison groups.

The mean verbal IQ for the SGA index group was 92.3 (SD 12.5) and for the AGA index group 90.8 (SD 14.5). The difference was not significant. The mean visual IQ for the SGA index group was 96.5 (SD 15.5) and for the AGA index group 95.4 (SD 17.8). Again the difference was not significant. The hypothesis that the SGA index children would gain a lower mean IQ scores than the AGA index children was not upheld. The direction of the differences was, again, opposite to that which was predicted – although none of the differences was significant at the 0.05 level.

The mean verbal IQ for the SGA comparison group was 94.9 (SD 14.5) and for the AGA comparison group 99.5 (SD 13.2) this difference was in the predicted direction but was not statistically significant. The mean visual IQ score for the SGA comparison group was 103.2 (SD 14.5) and for the AGA comparison group 107.8 (SD 15.1). The difference was in the predicted direction but, again, was not statistically significant.

All of the analyses reported above in relation to the investigation of SGA/AGA status and cognitive/scholastic outcome employed ANOVA with the Tukey HSD post hoc test. This is a stringent test of significance of difference between mean scores. It is, nevertheless, the appropriate test to use given the unequal numbers involved. When a less stringent post hoc test is employed (e.g. planned comparisons) or when differences between mean scores are analysed by t-test for independent samples, significant differences are elicited between mean scores of SGA and AGA comparison children on both verbal IQ and visual IQ.

(Details of all tests of significance of differences between mean scores are presented in Appendix 3).

TABLE 5.3.3

Mean general, verbal and visual IQs(British Ability Scales) by SGA/AGA status – index and comparison children

	VLBW SGA (N=92)	VLBW AGA (N=207)[x]	Comparison SGA (N=62)	Comparison AGA (N=429)
General IQ	94.1 (11.8)	92.8 (13.9)	98.5 (12.9)	103.0 (12.3)*
Verbal IQ	92.3 (12.5)	90.8 (14.5)	94.9 (14.5)	99.5 (13.2)
Visual IQ	96.5 (15.5)	95.4 (17.8)	103.2 (14.5)	107.8 (15.1)

*p<0.05; [x]One index child unable to complete all the subscales because of profound deafness

5.3.4 Comparison of scholastic attainment by SGA/AGA status

5.3.4.1 Comparison of mean Word Reading scores (BAS) and mean Number Skills scores (BAS) and numbers of children functioning <10th percentile by SGA/AGA status – index and comparison groups

The was little difference between mean Word Reading scores for the SGA index and AGA index children. The proportion of children functioning <10th percentile was greater for the AGA index group, 24% as compared with 14%, but the difference was not significant. Likewise, there was little difference between mean Number Skills scores for the SGA index and AGA index groups and the proportion of children functioning <10th percentile was also similar for both groups.

The mean Word Reading score for the SGA comparison group was 49.2 (SD 11.4) and for the AGA comparison group 54.0 (SD 10.8). This difference was significant and, moreover, a significantly greater proportion of the SGA comparison group were functioning <10th percentile – 19% as compared with 9% (χ^2 p<0.05). With regard to numeracy, the mean Number Skills score for the SGA comparison group was 46.6 (SD 9.8) and for the AGA comparison group 50.1 (SD 10.2) this difference was significant. While a greater proportion of the SGA comparison children were functioning <10th percentile – 15% as compared with 9%, the difference was not significant.

TABLE 5.3.4

Mean scores and numbers of children functioning below 10th percentile on school attainment tasks (British Ability Scales) - index children and comparison children by SGA/AGA status

	VLBW SGA (N=92) N (%)	VLBW AGA (N=208) N (%)	Comparison SGA (N=62) N (%)	Comparison AGA (N=429) N (%)
Word reading	50.6 (10.8)	49.2 (11.4)	49.2 (11.4)	54.0 (10.8)**
N below 10th percentile	13 (14)	49 (24)	12 (19)	39 (9)*
Number skills	43.9 (10.3)	44.5 (10.1)	46.6 (9.8)	50.1 (10.2)*
N below 10th percentile	25 (27)	50 (24)	9 (15)	38 (9)

*$p<0.05$

**$p<0.01$

*χ^2 $p<0.05$

In summary, as far as differences on measures of cognitive ability and scholastic attainment on the basis of SGA/AGA status are concerned, the hypotheses were not upheld for the index group and partially upheld for the comparison group.

Across the board the differences between the SGA index and AGA index children were not significant. The small differences that did exist were, in fact, in the opposite direction to that which was predicted – with the single exception of Speed of Information Processing. A possible explanation for this finding is that, because the study cohort is defined by birthweight <1500g, a gestational age bias comes into play when investigating differences by SGA/AGA status. In other, words the mean gestational age for the AGA index children is lower than that for the SGA index children. This implies that gestational age is more important than birthweight – this issue is explored in greater detail in Chapter 6.

For the comparison group the differences between mean general IQ scores and between mean reading and number skills scores were significant thus, to some extent, the hypotheses were upheld. The differences on all but one of the cognitive sub skills were in the predicted direction, but none was significant. The bias affecting the index group clearly does not affect the comparison group as birthweight is not bounded in the same way.

Section 4 Comparison of Index and Control Groups by Gender

5.4.1 Gender differences in cognitive ability

To test the hypothesis that there would be no differences between females and males in cognitive ability, mean IQ scores were compared by gender for both the index and comparison groups. Table 5.4.1.1 provides mean IQ (SD) scores for females and males in both the index and comparison groups. There is a difference of one IQ point between the female and male index children and almost no difference in the case of the comparison children.

The distribution of IQ by gender is based on the standard deviations for the respective comparison groups. This ensures that the comparison distributions are representative of contemporary Scottish children of eight to nine years of age. A slightly higher percentage of females than males in the index group has IQ scores falling more than 2 SD below the mean. The same was true also for those falling between 1 SD and 2 SD below the mean. A slightly higher proportion of males had IQ scores falling within the normal range. With regard to IQ scores falling in the above average range there were slightly more females than males – the numbers were, however, very small. As far as the comparison children were concerned there was very little difference between the genders in any of these groupings.

TABLE 5.4.1.1

Distribution of IQ by gender – index children and comparison children (using comparison group norms)

	VLBW Female (N=152)[x] N (%)	VLBW Male (N147) N (%)	Comparison Female (N298) N (%)	Comparison Male (N292) N (%)
Mean IQ (SD)	92.7 (12.7)	93.7 (13.9)	101.4 (12.2)	101.2 (12.6)
Number of children with IQ: (%)				
≥ 2 SD below mean - for comparison group	17 (11.2)	13 (8.8)	5 (1.7)	3 (1.0)
>1 – <2 SD below mean	48 (31.6)	43 (29.3)	42 (14.1)	40 (13.7)
1 SD below to 1 SD above the mean	78 (51.3)	85 (57.8)	200 (67.1)	202 (69.2)
>1 SD above mean	9 (5.9)	6 (4.1)	51 (17.1)	47 (16.1)

[x] One index child unable to complete all the subscales because of profound deafness.

The relative contributions of gender and case status to general IQ scores was investigated by a two-way ANOVA (dependent variable: general IQ; independent factors: gender and case status). The results are presented below, there was a strong contribution to IQ score differences by case status and almost none by gender. The box and whisker plot provides a graphic representation of the relative contributions of gender and case status to differences in IQ scores. (Levene's test for homogeneity of variance was not significant p>0.05.)

TABLE 5.4.1.2

Differences in mean General IQs by gender and case status: two – way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		mean=92.7	mean=93.7	mean=101.4	mean=101.2
VLBW	Female	(1)		0.916	0.000	0.000
VLBW	Male	(2)	0.916		0.000	0.000
Control	Female	(3)	0.000	0.000		1.000
Control	Male	(4)	0.000	0.000	1.000	

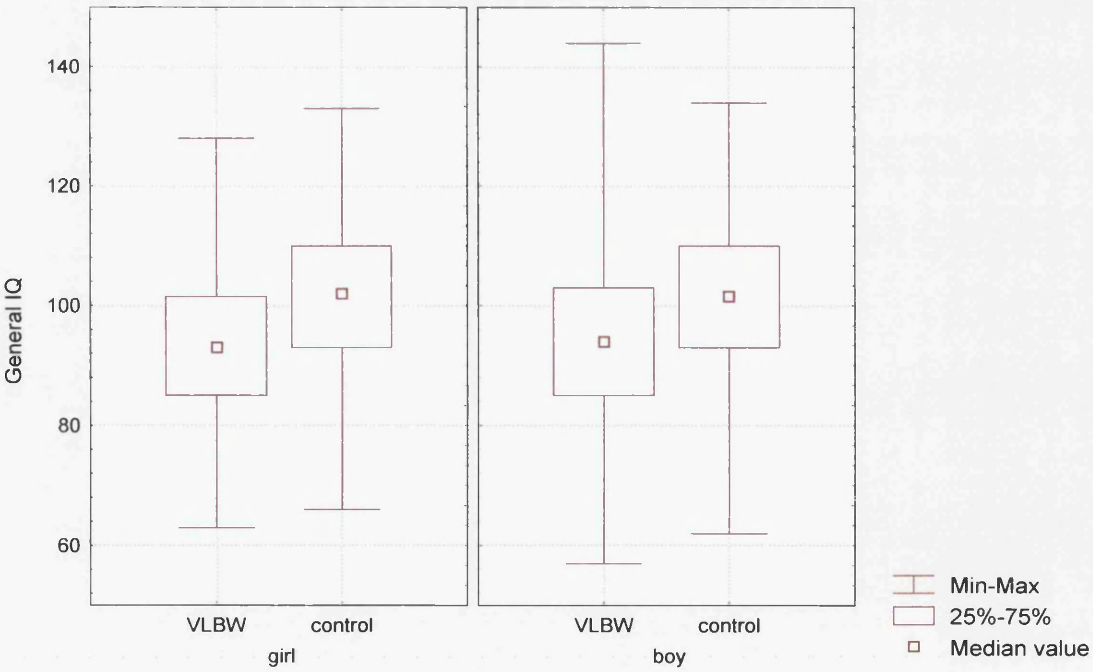

Figure 5.4.1 *Categorised box and whisker plot for general IQ by gender and case status*

5.4.2 Comparison of cognitive subskills scores by gender

The seven subtests of the BAS were investigated for gender differences. The mean scores (SD) for both the index and control groups by gender are presented below.

TABLE 5.4.2.
Mean cognitive sub skills score (SD) (British Ability Scales) by gender and case status

	VLBW Female (N=152)[x]	VLBW Male (N=147)	Comparison Female (N=298)	Comparison Male (N=292)
Ability Scales				
Similarities	48.7 (8.7)	48.0 (10.6)	50.8 (9.5)	51.0 (9.9)
Recall of Digits	48.1 (10.4)	48.3 (10.5)	49.7 (9.2)	48.3 (8.9)
Speed of Information Processing	47.3 (9.8)	47.3 (10.9)	51.8 (10.1)	52.7 (10.1)
Word Definitions	38.9 (9.2)	40.4 (10.0)	43.2 (9.7)	43.0 (9.1)
Matrices	46.1 (9.1)	45.7 (9.9)	50.6 (8.9)	49.4 (9.0)
Recall of Designs	49.8 (9.9)	51.8 (10.7)	55.3 (8.8)	55.6 (9.1)
Block Design	46.9 (10.5)	47.8 (11.4)	53.2 (9.2)	53.9 (10.3)

[x] One index child unable to complete all the subscales because of profound deafness.

The scores for both the index and comparison females and males are very similar. It is difficult to identify any differences at all. The average score on Recall of Designs was marginally higher for index males than for index females but the difference was not statistically significant. The results of the ANOVAs are presented in Appendix 1. As predicted no gender differences were found on any of the BAS subtests for the index group.

5.4.3 Comparison of verbal and visual composite IQ scores by gender

The visual and verbal IQ composite scores are computed from the subscales of the BAS. Given the similarity in the scores reported above it is unlikely that any differences would be found between index and comparison children on composite IQ scores. Differences were, however, investigated and are reported below.

TABLE 5.4.3
Mean general, verbal and visual IQs(British Ability Scales) by gender and case status

	VLBW Female (N=152)^{x}	VLBW Male (N=147)	Comparison Female (N=298)	Comparison Male (N=292)
General IQ	92.7 (SD 12.7)	93.7 (SD 13.9)	101.4 (SD 12.2)	101.2 (SD 12.6)
Verbal IQ	91.1 (SD 12.9)	91.4 (SD 15.0)	97.5 (SD 13.7)	97.3 (SD 13.2)
Visual IQ	94.9 (SD 16.8)	96.6 (SD 17.5)	106.5 (SD 14.7)	106.3 (SD 15.8)

^{x}One index child unable to complete all the subscales because of profound deafness.

As expected the differences between index females and males and between comparison females and males were negligible.

5.4.4 Comparison of scholastic attainment by gender

5.4.4.1 Comparison of mean Word Reading scores (BAS) and mean Number Skills scores (BAS) and numbers of children functioning <10th percentile by gender – index and comparison groups

The table below presents the mean Word reading and Number skills scores by gender for the index and comparison groups.

TABLE 5.4.4.1
Mean scores and numbers of children functioning below 10th percentile on school attainment tasks (British Ability Scales) - index children and comparison children by gender

	VLBW Female (N=153) N (%)	VLBW Male (N147) N (%)	Comparison Female (N298) N (%)	Comparison Male (N292) N (%)
Word reading	49.5 (SD 10.5)	49.8 (SD 11.9)	52.7 (SD 10.0)	52.7 (SD 11.8)
N below 10th percentile	29 (19.0)	33 (22.5)	24 (8.1)	43 (14.7)**
Number skills	44.2 (SD 9.5)	44.5 (SD 10.8)	50.2 (SD 9.8)	48.1 (SD 10.2)*
N below 10th percentile	34 (22.2)	41 (27.9)	22 (7.3)	41 (14.0)**

*$p<0.05$

**χ^2 $p<0.01$

No significant difference between mean reading or number scores for female and male index children was found – nor was there any difference in the proportion of females and males performing below the 10th percentile in either reading or number.

There was no significant difference between mean reading scores of female and male comparison children, although a significantly greater proportion of the male children scored below the 10th percentile (χ^2 $p<0.01$). The difference between mean number skills scores for female and male comparison children was significant ($p<0.05$ two-way ANOVA and Tukey HSD post hoc test – refer to Appendix 5) with females gaining, on average, higher scores than the males. There was also a significantly greater proportion of male children performing below the 10th percentile on number skills (χ^2 $p<0.01$).

Section 5 Comparison of Index and Control Groups by Birthweight Groupings: <1000g and 1000-1499g

5.5.1 Characteristics of the index and comparison groups by birthweight groupings

The sociodemographic characteristics of the index and comparison groups were reported in the first section of this chapter. The table below presents the same information as previously reported but this time by birthweight groupings.

TABLE 5.5.1

Socio demographic characteristics of the index and comparison groups by birthweight groupings

	<1000g (N=45)	Comparison A (N=90)	1000-1499g (N=255)	Comparison B (N=500)
Age at assessment (years)	8.8 (0.3)	8.7 (0.4)	8.8 (0.3)	8.8 (0.4)
Maternal age (years)	35.0 (5.7)	35.1 (4.6)	35.3 (6.1)	37.1 (5.8)
Paternal age (years)	37.2 (7.8)	37.3 (5.1)	37.6 (7.2)	37.1 (5.8)
Parental social class				
I,II and III NM	12 (27)	28 (31)	53 (21)	138 (28)***
III M	11 (24)	29 (32)	65 (26)	141 (28)
IV and V	4 (9)	10 (11)	34 (13)	85 (17)
Unknown	18 (40)	23 (26)	103 (40)	136 (27)
Parental educational qualifications				
None	12 (27)	19 (21)	62 (24)	105 (21)*
O grades/apprenticeship	19 (42)	32 (36)	87 (34)	212 (42)
Higher education	8 (18)	28 (31)	48 (19)	104 (21)
Unknown	6 (13)	11 (12)	58 (23)	79 (16)
Single parent family	10 (25)	11 (14)	44 (22)	59 (14)**
Father unemployed > 1 year	6 (18)	7 (10)	36 (20)	44 (11)***

Numbers in first three rows are Mean (SD); numbers in rest of table are N (%).

*$p<0.05$ *(Source: Hall et al., 1995)*

**$p<0.01$

***$p<0.005$.

Considering the sociodemographic information obtained from the parental questionnaires by birthweight groupings paints essentially the same picture as reported above. Neither pairing of index and comparison groups differed in respect of their father's and mother's age at the time of the assessment. The occupation of more of the index children's parents was unknown. Both index groups would appear to have fewer parents in non manual occupations, but the differences in social class distributions was significant only for those weighing 1000g to 1499g at birth ($p<0.005$). There were also differences in the distribution of parental educational levels between the index groups and their comparison groups, but this difference was statistically significant only for the children weighing 1000g to 1499g at birth ($p<0.05$). Among the ELBW children fewer parents had received higher education (18 per cent *vs.* 31 per cent) but the difference was not significant. More of the very low birthweight children were currently living in single parent households, but this difference was, again, statistically significant only for those in the 1000g to 1499g group; significantly more of this group also had fathers who had been unemployed for more than one year.

5.5.2 Comparison of scores of cognitive ability and educational attainment by birthweight groupings

The mean IQ scores and the distributions of IQ by birthweight groupings are presented in the table below.

TABLE 5.5.2.1

Distribution of IQ by birthweight groupings – index children and comparison children (using comparison group norms)

	<1000g (N=44[x]) N (%)	Comparison A (N=90) N (%)	1000-1499g (N=255) N (%)	Comparison B (N=500) N (%)
Mean IQ (SD)	90.4 (11.2)	102.5 (12.4)***	93.7 (13.6)	101.1 (12.4)***
Number of children with IQ: (%)				
≥ 2 SD below mean - for comparison group	6 (14)	3 (3)*	27 (11)	9 (2)**
>1 – <2 SD below mean	18 (41)	10 (11)*	69 (27)	70 (14)**
1 SD below to 1 SD above the mean	19 (43)	63 (70)	146 (57)	342 (68)
>1 SD above mean	1 (2)	14 (16)*	13 (5)	79 (16)**

*χ^2 $p<0.05$

**χ^2 $p<0.001$

***$p<0.0001$

[x] One index child unable to complete all the subscales because of profound deafness.

The mean general IQ for the ELBW group was 90.4 (SD 11.1) and for their comparison group A was 102.5 (SD 12.4). The mean general IQ for the group of index children with birthweights between 1000g and 1499g was 93.7 (SD 13.6) compared to 101.1 (SD 12.4). In both cases the index groups had, on average, statistically significantly lower cognitive abilities.

TABLE 5.5.2.2
Difference in mean IQ scores - index (<1000g) versus comparison children

	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Index group	44	90.4	11.2	-5.44	132	0.000	0.49	132	0.49
Comparison group	90	102.5	12.4						

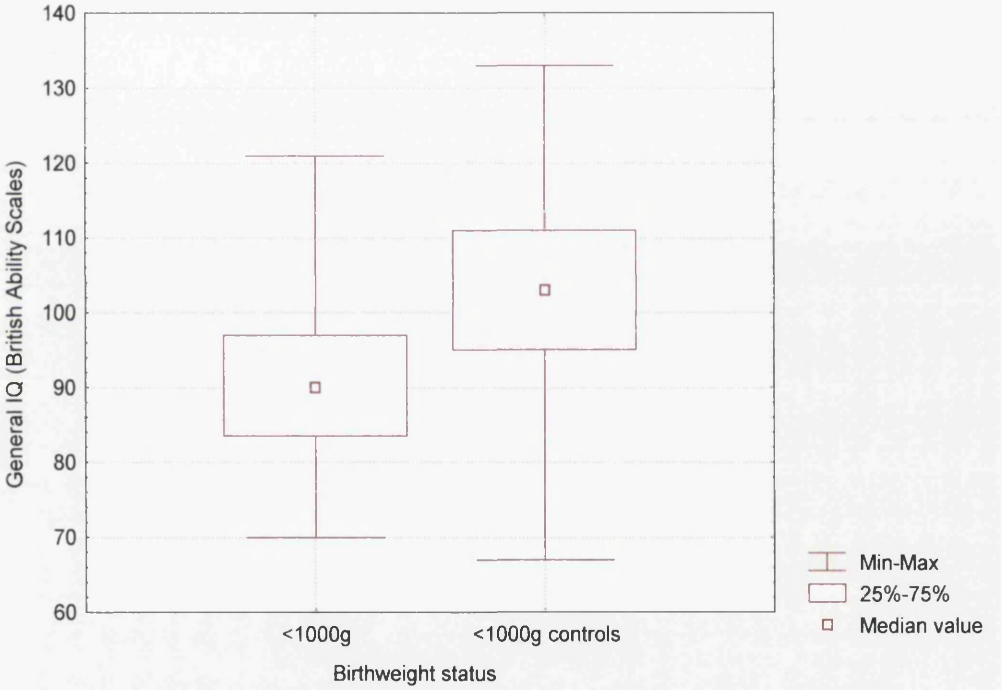

Figure 5.5.2.1 *Box and whisker plot for general IQ by case status (<1000g and controls)*

Levene's test for homogeneity of variance was significant for the ELBW group. As mentioned above, when group sizes exceed 30, then it is reasonable to assume homogeneity of variance. There were 44 children in the index group who were able to complete the assessment and 90 in the comparison group. It is assumed, therefore, that there is homogeneity of variance and that the difference in mean scores between the two groups is significant.

TABLE 5.5.2.3
Difference in mean IQs - index (1000-1499g) versus comparison children

	N	Mean	SD	t-value	df	P	Levene F (1, df)	df	P Levene
Index group	255	93.7	13.6	-7.47	753	0.000	1.93	753	0.17
Comparison group	500	101.1	12.4						

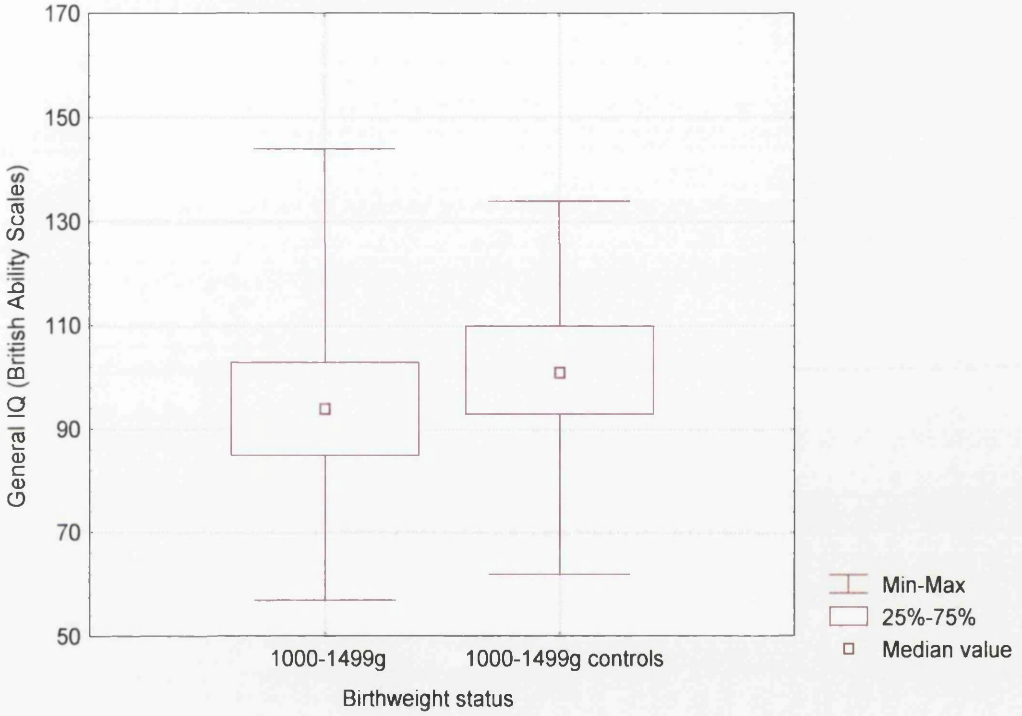

Figure 5.5.2.2 *Box and whisker plot for general IQ by case status (1000 - 1499g and controls)*

Six (14%) of the ELBW children in mainstream education had IQs more than 2 SD below the mean, as did three (3%) of their controls. Those index children with birthweights between 1000g and 1499g were five times more likely to have IQs more than 2 SD below the mean than were their classroom controls, with a marked tendency for poorer performance in this group ($p<0.001$). There is, therefore, a considerable proportion of index children who would be regarded as having special educational needs and are being educated in mainstream education. This raises issues regarding the considerable learning support needs of these children. The issue of the provision of learning support is discussed in Chapter 6.

TABLE 5.5.2.4

Mean T scores for cognitive sub-skills and scholastic attainment(British Ability Scales) by birthweight grouping - index children and comparison children

	<1000g		*Comparison A*		*1000g –1499g*		*Comparison B*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Ability Scales								
Similarities	48.3	9.6	51.9	10.0	48.4	9.7	50.7	9.6*
Recall of Digits	50.1	10.7	49.4	9.1	47.8	10.4	48.9	9.1
Speed of Information Processing	45.4	11.8	52.6	10.2**	47.7	10.1	52.2	10.1***
Word Definitions	37.6	9.1	43.3	9.5**	39.9	9.7	43.1	9.4***
Matrices	43.0	9.2	50.8	7.9***	46.4	9.4	49.9	9.1***
Recall of Designs	47.6	8.9	56.0	8.8***	51.4	10.5	55.4	9.0***
Block Design	45.2	9.1	54.1	9.3***	47.7	11.2	53.5	9.9***

*p<0.05
**p<0.001
***p<0.0001

The details of the tests of significance are presented in Appendix 2.

TABLE 5.5.2.5

Mean general, verbal and visual IQs(British Ability Scales) by birthweight grouping - index children and comparison children

	<1000g		*Comparison A*			*1000g –1499g*		*Comparison B*		
	Mean	*(SD)*	*Mean*	*(SD)*	*95% CI*	*Mean*	*(SD)*	*Mean*	*(SD)*	*95% CI*
General IQ	90.4	(11.1)	102.5	(12.4)***		93.7	(13.6)	101.1	(12.4)***	
Verbal IQ	90.6	(10.9)	98.5	(13.6)**	(-12.6, -3.2)	91.4	(14.4)	97.3	(13.4)***	(-8.0, -3.8)
Visual IQ	89.9	(14.9)	107.8	(14.8)***	(-23.2, -12.5)	96.8	(17.3)	106.2	(15.2)***	(-11.8, -7.0)

**p<0.001

***p<0.0001

TABLE 5.5.2.6

Mean scores and numbers of children functioning below 10th percentile (for respective comparison groups) on school attainment tasks(British Ability Scales) by birthweight grouping - index children and comparison children

	<1000g		*Comparison A*		*95% CI*	*1000g –1499g*		*Comparison B*		*95% CI*
	Mean	*(SD)*	*Mean*	*(SD)*		*Mean*	*(SD)*	*Mean*	*(SD)*	
Word reading	47.9	(11.2)	53.2	(10.6)**	(-9.2, -1.4)	49.9	(11.2)	52.6	(10.9)*	(-4.4, -1.0)
N below 10th percentile	12	(26.7%)	10	(11.1%)**		50	(19.6%)	57	(11.4%)****	
Number skills	40.0	(9.1)	48.9	(10.1)***	(-12.4, -5.3)	45.1	(10.1)	49.2	(10.0)***	(-5.6, -2.6)
N below 10th percentile	17	(37.8%)	9	(10.0%)***		56	(22.0%)	52	(10.4%)*****	

*p<0.05 ***χ^2 p<0.005

p<0.01 **χ^2 p<0.001

p<0.005 **χ^2 p<0.0001

Table 5.5.2.4 above provides details of the performance of the index group by birthweight groupings in the subscales of the BAS. The index group below 1000g performed significantly less well than their comparisons on all scales with the exception of Recall of Digits and Verbal Reasoning. Verbal reasoning, like Recall of Digits, belongs to the verbal cluster of scores.

The picture for the 1000-1499g index children was exactly the same as for the index group as a whole. Performance on all items of the BAS, with the exception of Recall of Digits, was significantly poorer than for their comparisons.

Table 5.5.2.5 demonstrates that for both the index groups verbal IQ and visual IQ composite scores were significantly lower than for the comparison groups.

The results for scholastic attainment by birthweight groupings are presented in Table 5.5.2.6 The word reading scores for both index groups are relatively strong – with mean T scores falling not far below the mean for the test. However, the differences in mean word reading scores between index and comparison children in both groupings were statistically significant. Furthermore, a significantly greater proportion of children in both index groupings were performing below the 10th percentile for the comparison group.

Mean number skills T scores were, in general poorer for both index and control children – the index children below 1000g performed particularly poorly. Again the differences in mean scores between index and comparison children in both groupings were statistically significant. More than a quarter of all index children below 1000g were performing below the 10th percentile for the comparison group – and almost a quarter of those index children 1000-1499g. Again a significantly greater proportion of children in both index groupings were performing below the 10th percentile for the comparison group

5.5.3 The influence of IQ on poor performance on measures of scholastic attainment

As indicated in Section 2 of this chapter above, it is possible that the differences on measures of educational attainment between the index and comparison groups could be accounted for more in terms of differences in IQ rather than birthweight differences. To investigate this possibility reading and number scores for the index and comparison groups were compared while controlling for general IQ (ANCOVA).

5.5.3.1 Number skills

To investigate the possibility that general IQ is responsible for some of the difference in performance in number skills, number scores for the index males and females and comparison males and females were compared while controlling for general IQ (ANCOVA). Table 5.5.3.1.1 demonstrates the effects of case and gender without entering general IQ in the model as a covariate. The p-level for case is significant for both birthweight groupings.

Table 5.5.3.1.1
Differences between index and comparison females and males on basic number skills without controlling for general IQ – by birthweight groupings

	Below 1000g			1000-1499g		
	MS Effect	F	p-level	MS Effect	F	p-level
Case	2263.7	23.547	0.000	2888.3	28.650	0.000
Gender	159.9	1.664	0.199	116.1	1.151	0.284
Case x gender	0.1	0.001	0.978	287.8	2.854	0.092

Table 5.5.3.1.2 below and demonstrates that, after entering general IQ in the ANCOVA model, the difference in number scores by case is no longer significant – although this is marginal for the below 1000g group. As noted above gender is now having more of an effect especially for the 1000-1499g group – although not significantly so.

Table 5.5.3.1.2
Differences between index and comparison females and males on basic number skills controlling for general IQ (ANCOVA) – by birthweight groupings

	Below 1000g			1000-1499g		
	MS Effect	F	p-level	MS Effect	F	p-level
Case	227.8	3.378	0.068	150.0	2.120	0.146
Gender	43.0	0.638	0.426	253.4	3.582	0.059
Case x gender	4.72	0.070	0.791	155.6	2.199	0.138

5.5.3.2 Reading skills

The investigation was repeated in relation to reading scores for the index males and females and comparison males and females. Again the first table demonstrates the effects of case and gender without entering general IQ in the model as a covariate. Once again the p-level for case is significant for both groupings.

Table 5.5.3.2.1
Differences between index and comparison females and males on word reading skills without controlling for general IQ – by birthweight groupings

	Below 1000g			1000-1499g		
	MS Effect	F	p-level	MS Effect	F	p-level
Case	964.5	8.228	0.005	1233.5	10.095	0.002
Gender	72.2	0.616	0.434	25.2	0.207	0.650
Case x gender	141.0	1.203	0.275	38.5	0.315	0.575

Table 5.5.3.2.2 below demonstrates that, after controlling for general IQ, the effect of case difference on reading skills is no longer significant – for either birthweight grouping.

Table 5.5.3.2.2
Differences between index and comparison females and males on word reading skills controlling for general IQ (ANCOVA) – by birthweight groupings

	Below 1000g			1000-1499g		
	MS Effect	F	p-level	MS Effect	F	p-level
Case	56.19	0.809	0.370	47.49	0.526	0.469
Gender	0.735	0.011	0.918	0.08	0.001	0.976
Case x gender	76.03	1.095	0.297	2.52	0.028	0.867

The implication of this investigation is that the significant differences observed between both index and comparison groupings in number and reading cannot be attributed solely to birthweight status. General intelligence is clearly a factor in these differences and gender would also appear to be influencing differences in certain areas.

Section 6 Assessment of Motor Competence and Neurological Functioning

5.6.1 Motor competence

5.6.1.1 Movement Assessment Battery for Children – index children versus comparison children

The Movement Assessment Battery for Children was used as the measure of motor competence. A surprisingly high proportion of the comparison children were found to be performing below the 10th percentile. Following consultation with the test author it was decided to use the 10th percentile for the comparison group as the cut off for impaired motor functioning.

Excluding those children who were in special schools, because they had no controls, the index children performed less well than the comparison group on the Movement ABC test (Table 5.6.1.1). Approximately one in every three index children would be regarded as having impaired motor functioning.

Table 5.6.1.1.1 Numbers (%) of children falling below the 10th percentile (for the control children) on the Movement Assessment Battery for Children: VLBW and comparison groups

	VLBW (all <1500g) (N=300)		*Comparison (N=590)*		
	N	*(%)*	*N*	*(%)*	*P*
Movement ABC <10th percentile	180	(36)	62	(11)	<0.0001

This applied not only to the overall Movement ABC score but also to the three areas of motor competence assessed – ball skills, manual dexterity and balance. In terms of performance on individual items within these areas, the index group performed relatively well at throwing a beanbag into a box and at moving pegs on a pegboard with the non preferred hand, but even on these two items the difference between their performance and that of the comparison groups was statistically significant (Table 5.6.1.1.2).

There was little variation across the items for the comparison group with the exception of balancing on a board (Chapter 4, figure 4.3) with the preferred leg – which 14% of the children were unable to perform satisfactorily. This, too, was a particularly problematic item for the index children.

TABLE 5.6.1.1.2

Numbers (%) of children falling <10th centile for competence at eight years of age

VLBW and comparison groups

	VLBW (all <1500g) (N=300)		*Comparison (N=590)*		
	N	*(%)*	*N*	*(%)*	*P*
Ball Skills					
Two-Handed Catch	80	(27)	61	(10)	<0.0001
Throwing the Beanbag	38	(13)	40	(7)	<0.01
Manual Dexterity					
Threading Nuts on Bolt	73	(24)	54	(9)	<0.0001
Flower Trail	72	(24)	56	(9)	<0.0001
Peg Board (preferred hand)	65	(22)	55	(9)	<0.0001
Peg Board (non-preferred hand)	48	(16)	50	(8)	<0.01
Balance					
One Board Balance (preferred leg)	92	(31)	84	(14)	<0.0001
One Board Balance (non-preferred leg)	61	(20)	35	(6)	<0.0001
Hopping (preferred leg)	39	(13)	34	(6)	<0.001
Hopping (non-preferred leg)	65	(22)	55	(9)	<0.0001
Ball Balance	94	(31)	62	(11)	<0.0001

5.6.1.2 Neurological functioning – index children versus comparison children

To test the hypothesis that a higher proportion of index children than comparison children would have impaired neurological functioning the Quick Neurological Screening Test (QNST) was administered. Performance on the QNST was significantly worse for the index group (Table 5.6.1.2.1).

Table 5.6.1.2.1 Overall performance on the Quick Neurological Screening Test: VLBW and comparison groups

	VLBW (all <1500g) (N=300)		*Comparison (N=590)*		
QNST score	*N*	*(%)*	*N*	*(%)*	*P*
Normal	119	(40)	451	(76)	<0.0001
Suspicious	157	(52)	136	(23)	<0.0001
Abnormal	15	(5)	1	(<1)	<0.0001
Unable to complete	9	(3)	2	(<1)	<0.005

The significance of the differing proportions of children falling into each of the classifications of the QNST was tested using the 2x2 Chi square statistic. The results presented above demonstrate that a significantly greater proportion of comparison children gained “normal” scores and a significantly greater proportion of index children gained “suspicious” or “abnormal” scores.

Only 40% of the index group achieved normal scores as compared with 76% for the comparison group. Just one child (0.2%) in the comparison group had an abnormal overall score whereas 15 (5%) of children in the index group fell into this category.

More than half of the index group had scores in the suspicious category and the scores of a large proportion of the comparison group (23%) also fell into this category.

Individual activities that were relatively intact in the index group included hand skill (a paper and pencil exercise to examine hand preference and to identify tremors and/or visual impairment) and skipping (an activity, designed to identify problems in gross motor movement, whereby the child is required to skip across a room). Those activities where the index group experienced most problems included double simultaneous stimulation of hand and cheek (to identify problems with intrabody communication and tactile deficits by inability to detect touch to hand and cheek simultaneously), finger to nose (to identify difficulties of knowledge of body position and orientation in space by failure to move hand from examiner's finger to own nose with eyes closed) and rapidly reversing repetitive hand movements (- to identify motor planning difficulties by inability to move hand simultaneously in a rapid reversing movement).

A sizeable minority of the comparison group also experienced difficulty with the double simultaneous stimulation of hand and cheek item. Other than this the comparison group had no particular area of difficulty.

A relatively small proportion of both the index and comparison group had high scores on sound patterns but both groups had a large proportion of suspicious scores. Sound patterns is an activity designed to identify immature auditory sensory-motor skills by an inability to reproduce patterns of sounds by tapping hands on knees. It overlaps, to some extent, with Recall of Digits (BAS) in that it places a demand on short term auditory sequential memory, but it also requires motor planning which Recall of Digits does not.

Performance of the index and comparison groups on all of the individual activities of the QNST is presented in table 5.6.1.2.2.

TABLE 5.6.1.2.2

Performance on individual items of Quick Neurological Screening Test: VLBW and comparison groups

	VLBW (all <1500g) (N=300)				*Comparison (N=590)*			
	Normal	*Suspicious*	*High*	*Unable to complete*	*Normal*	*Suspicious*	*High*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	266 (89)	31 (10)	3 (1)	0 (0)	576 (98)	14 (2)	0 (0)	0 (0)
Figure recognition	181 (60)	104 (35)	15 (5)	0 (0)	447 (75)	140 (24)	3 (1)	0 (0)
Palm form	182 (60)	96 (32)	20 (7)	2 (1)	431 (73)	146 (25)	11 (2)	2 (0.3)
Eye tracking	237 (79)	43 (14)	20 (7)	0 ()	558 (95)	27 (4)	5 (1)	0 (0)
Sound patterns	71 (23)	224 (75)	3 (1)	2 (1)	275 (47)	309 (52)	6 (1)	0 (0)
Finger to nose	190 (63)	64 (21)	45 (15)	1 (0.3)	473 (80)	82 (14)	35 (6)	0 (0)
Thumb and finger circle	187 (63)	94 (31)	16 (5)	3 (1)	429 (73)	149 (25)	12 (2)	0 (0)
Double simultaneous stimulation of hand and cheek	53 (18)	197 (65)	50 (17)	0 (0)	164 (28)	360 (61)	66 (11)	0 (0)
Rapidly reversing repetitive hand movements	98 (33)	153 (51)	47 (15)	2 (1)	283 (48)	258 (44)	47 (8)	2 (0.3)
Arm and leg extensions	43 (14)	229 (77)	28 (9)	0 (0)	222 (38)	359 (61)	9 (1)	0 (0)
Tandem walk	202 (68)	81 (27)	13 (4)	4 (1)	518 (88)	70 (12)	2 (0.3)	0 (0)
Standing on one leg	231 (77)	43 (14)	23 (8)	3 (1)	554 (93)	30 (6)	6 (1)	0 (0)
Skipping	269 (89)	23 (8)	5 (2)	3 (1)	569 (96)	20 (4)	1 (0.2)	0 (0)
Left-right discrimination and hand-eye-foot preference	208 (69)	91 (30)	0 (0)	1 (0.3)	445 (75)	145 (25)	0 (0)	0 (0)
Behaviour	275 (92)	20 (7)	4 (1)	1 (0.3)	577 (98)	9 (1.5)	4 (0.5)	0 (0)

Section 7 Comparison of Children who were Small for Gestational Age (SGA) and Children who were Appropriate Birthweight for Gestational AGE (AGA) on tests of Neuromotor Functioning.

5.7.1 Motor competence

5.7.1.1 Performance on the Movement Assessment Battery for Children by SGA/AGA status – for index and comparison children

It was predicted that a greater proportion those index children who were small for gestational age (SGA) would have Movement ABC scores <10th percentile than those index children who were of appropriate size for gestational age (AGA). On the assumption that being small for gestational age is disadvantageous as far as motor development is concerned, it was also predicted that a greater proportion those comparison children who were SGA would have Movement ABC scores <10th percentile than those comparison children who were AGA.

The results of the Movement ABC overall score (Table 5.7.1.1) demonstrate that there were no significant differences between the SGA and AGA index children. Across all the individual items of the Movement ABC, with the exception of throwing the beanbag and one board balance, a greater proportion of the AGA children gained scores <10th percentile – but only in the case of moving pegs on a pegboard with the preferred hand was this difference significant.

The overall picture is the reverse for the comparison children. Again there was no significant difference between the SGA and AGA children in terms of the overall Movement ABC score. As far as the individual items were concerned a greater proportion of the SGA children gained scores falling below the 10th percentile in all but two handed catch and moving pegs on a pegboard with the preferred hand. The differences, however, were not significant except for hopping – both with the preferred leg and the non preferred leg.

TABLE 5.7.1.1

Numbers (%) of children falling <10th centile for motor skills at eight years of age by SGA/AGA status: VLBW and comparison groups by birthweight groupings

	VLBW SGA (N=92)		VLBW AGA (N=208)			Comparison SGA (N=62)		Comparison AGA (N=429)		
	N	*(%)*	*N*	*(%)*	*P*	*N*	*(%)*	*N*	*(%)*	*P*
Overall Movement ABC score	28	(30)	80	(38)		8	(13)	42	(10)	
Ball Skills										
Two-Handed Catch	23	(25)	57	(28)		4	(6)	52	(12)	
Throwing the Beanbag	13	(14)	25	(12)		6	(10)	29	(7)	
Manual Dexterity										
Threading Nuts on Bolt	20	(22)	53	(26)		7	(11)	38	(9)	
Flower Trail	18	(20)	54	(26)		8	(13)	35	(8)	
Peg Board (preferred hand)	12	(13)	53	(26)	$p<0.05$	4	(6)	37	(9)	
Peg Board (non-preferred hand)	10	(11)	38	(18)		8	(13)	34	(8)	
Balance										
One Board Balance (preferred leg)	29	(32)	63	(30)		11	(18)	57	(13)	
One Board Balance (non-preferred leg)	22	(24)	39	(19)		3	(5)	22	(5)	
Hopping (preferred leg)	9	(10)	30	(14)		7	(11)	20	(5)	$p<0.05$
Hopping (non-preferred leg)	16	(17)	49	(24)		10	(16)	32	(7)	$p<0.05$
Ball Balance	24	(26)	70	(34)		8	(13)	41	(10)	

5.7.1.2 Performance on the Quick Neurological Screening Test by SGA/AGA status – index children and comparison children

To test the hypothesis that a higher proportion of SGA index children than AGA index children would have impaired neurological functioning, performance on the Quick Neurological Screening Test (QNST) was analysed by SGA/AGA status.

It was also predicted that the SGA comparison children would be more likely to be classified as suspicious or abnormal than their AGA counterparts.

There was no difference between the SGA and AGA index children, the proportions categorised as normal and as suspicious were very similar (Table 5.7.1.2). A significantly higher proportion of AGA children had abnormal scores on the QNST although the numbers were very small – only one child in the SGA index group had an abnormal score.

In the comparison group 69% of the SGA group had normal scores as compared with 79% of the AGA group and 31% of the SGA group had suspicious scores as compared with 21% of the AGA group – these differences were not, however, significant.

The general pattern for the QNST reflects that for the Movement ABC, that is, although the differences were not significant, there is a pattern whereby a smaller proportion of the SGA VLBW had scores <10th percentile on almost all of the Movement ABC items and a smaller percentage were categorised as suspicious or abnormal on the QNST. In the case of the comparison group, exactly the reverse is true. That is, a smaller proportion of the AGA children had scores <10th percentile on the Movement ABC items and a smaller percentage were categorised as suspicious – again, however, none of the differences was significant. None of the comparison group, either SGA or AGA, was classified as abnormal on the QNST.

TABLE 5.7.1.2

Overall performance on the Quick Neurological Screening Test at eight years of age by SGA/AGA status: VLBW and comparison children

	VLBW		VLBW			Comparison		Comparison		
	SGA		AGA			SGA		AGA		
	(N=92)		(N=208)			(N=62)		(N=429)		
QNST	*N*	*(%)*	*N*	*(%)*	*P*	*N*	*(%)*	*N*	*(%)*	*P*
Normal	36	(39)	83	(40)		43	(69)	339	(79)	
Suspicious	51	(56)	106	(51)		19	(31)	88	(21)	
Abnormal	1	(1)	14	(7)	$p<0.05$	0	(0)	0	(0)	
Unable to complete	4	(4)	5	(2)		0	(0)	2	(0.4)	

Section 8 Comparison of Neuromotor Functioning by Gender

5.8.1 Motor competence

5.8.1.1 Performance on the Movement Assessment Battery for Children by gender – for index and comparison children

It was predicted that a similar proportion of VLBW females and males would gain scores falling <10th percentile. It was also predicted that the same would be true for the comparison group. The result of the performance of the VLBW and comparison children on the Movement ABC were analysed by gender and are presented in Table 5.8.1.1.

There were few significant differences between index males and females. The only area of motor functioning where a difference was noted was ball skills. On both the activities that contribute to this composite, namely, two handed catch and throwing the beanbag, significantly more females were performing below the 10th percentile.

The same was true for the comparison females. They too performed more poorly on the ball skills elements of the Movement ABC.

There were no differences between females and males on tests of manual dexterity or balance in either the index or comparison groups.

TABLE 5.8.1.1

Numbers (%) of children falling <10th centile for motor skills at eight years of age by gender: VLBW and comparison groups by birthweight groupings

	VLBW		VLBW			Comparison		Comparison		
	Female		Male			Female		Male		
	(N=153)		(N=147)			(N=298)		(N=292)		
	N	*(%)*	*N*	*(%)*	*P*	*N*	*(%)*	*N*	*(%)*	*P*
Overall Movement ABC score	60	(39)	48	(33)		31	(10)	31	(11)	
Ball Skills										
Two-Handed Catch	52	(34)	28	(19)	$p<0.05$	45	(15)	16	(5)	$p<0.001$
Throwing the Beanbag	28	(18)	10	(7)	$p<0.01$	30	(10)	10	(3)	$p<0.005$
Manual Dexterity										
Threading Nuts on Bolt	43	(28)	30	(20)		30	(10)	24	(8)	
Flower Trail	43	(28)	29	(20)		29	(10)	27	(9)	
Peg Board (preferred hand)	33	(22)	32	(22)		24	(8)	31	(11)	
Peg Board (non-preferred hand)	24	(16)	24	(16)		23	(8)	27	(9)	
Balance										
One Board Balance (preferred leg)	46	(30)	46	(31)		40	(13)	44	(15)	
One Board Balance (non-preferred leg)	26	(17)	35	(24)		11	(7)	24	(8)	
Hopping (preferred leg)	18	(12)	21	(14)		11	(7)	23	(8)	
Hopping (non-preferred leg)	26	(17)	39	(27)		25	(8)	30	(10)	
Ball Balance	47	(31)	47	(32)		26	(9)	36	(12)	

5.8.1.2 Performance on the Quick Neurological Screening Test by gender – index children and comparison children

To test the hypothesis that there would be no difference in neurological functioning between female and male index children performance on the Quick Neurological Screening Test (QNST) was analysed by gender. It was predicted that the proportion of females and males classified as suspicious or abnormal would be similar.

It was also predicted that the proportions of female and male comparison children classified as suspicious or abnormal would be similar.

The results are presented in Table 5.8.1.2

There was no difference between the female and male index children in terms of the proportion categorised as normal or suspicious. Significantly more males were classified as abnormal – although the numbers in this category were small – three females (2%) and 12 males (8%).

There was no difference between the female and male comparison children in terms of the proportion classified as normal. Significantly more males than females had suspicious scores; 81 (28%) versus 55 (18%). With regard to comparison children classified as abnormal, just one male child and no females fell within this category.

TABLE 5.8.1.2

Overall performance on the Quick Neurological Screening Test at eight years of age by genders: VLBW and comparison children

	VLBW female (N=153)		VLBW male (N=147)			Comparison female (N=298)		Comparison male (N=292)		
QNST	*N*	*(%)*	*N*	*(%)*	*P*	*N*	*(%)*	*N*	*(%)*	*P*
Normal	73	(48)	46	(31)		242	(81)	209	(72)	
Suspicious	74	(48)	83	(57)		55	(18)	81	(28)	p<0.05
Abnormal	3	(2)	12	(8)	p<0.05	0	(0)	1	(0.5)	
Unable to complete	3	(2)	6	(4)		1	(0.5)	1	(0.5)	

Section 9 Comparison of Neuromotor Functioning by Birthweight Groupings

5.9.1 Motor competence

5.9.1.1 Performance on the Movement Assessment Battery for Children by birthweight groupings – for index and comparison children

To enable the results of the present study to be discussed in relation to those studies reporting upon the outcomes of ELBW infants, the index group was separated into two birthweight groupings: below 1000g and 1000-1499g. It was predicted that a greater proportion of both the index groups would be experiencing motor impairment than their respective comparison groups.

The results of the index group on the Movement ABC by birthweight groupings are presented below together with the results for their respective comparison groups (Table 5.9.1.1).

As predicted both the below 1000g index group and the 1000-1499g index group performed less well than their comparison groups on Movement ABC. This applied both their overall scores on the Movement ABC and to their performance on almost all of the individual items.

The VLBW group, as a whole, had performed relatively well at throwing the beanbag into a box and moving pegs on a pegboard with the non preferred hand – although the scores of the index children had still been significantly lower than those of the comparison children. When throwing the beanbag was investigated by birthweight groupings there was no significant difference between either the <1000g or the 1000-1499g index groups and their respective comparison groups. With regard to moving the pegs on a pegboard, the 1000-1499g index children were found to be at no greater disadvantage than their comparison group for the non preferred hand but the performance of the below 1000g index children was significantly poorer than that of their comparison group for both the preferred and non preferred hand.

TABLE 5.9.1.1

Numbers (%) of children falling <10th centile for motor skills at eight years of age: VLBW and comparison groups by birthweight groupings

	Index (<1000g)		Comparison (A)			Index (1000-1499g)		Comparison (B)		
	N	*(%)*	*N*	*(%)*	*P*	*N*	*(%)*	*N*	*(%)*	*P*
Overall Movement ABC score	22	(50)	7	(8)	<0.001	86	(34)	55	(11)	<0.001
Ball Skills										
Two-Handed Catch	14	(32)	6	(7)	<0.001	66	(26)	55	(11)	<0.001
Throwing the Beanbag	10	(22)	7	(8)		28	(11)	33	(7)	
Manual Dexterity										
Threading Nuts on Bolt	15	(33)	11	(12)	<0.01	58	(23)	43	(9)	<0.001
Flower Trail	15	(33)	10	(11)	<0.01	57	(22)	46	(9)	<0.001
Peg Board (preferred hand)	16	(36)	5	(6)	<0.001	49	(19)	50	(10)	<0.001
Peg Board (non-preferred hand)	13	(30)	5	(6)	<0.001	35	(14)	45	(9)	
Balance										
One Board Balance (preferred leg)	16	(36)	10	(11)	<0.001	76	(30)	74	(15)	<0.001
One Board Balance (non-preferred leg)	12	(27)	4	(4)	<0.001	49	(19)	31	(6)	<0.001
Hopping (preferred leg)	10	(23)	4	(4)	<0.01	29	(12)	30	(6)	<0.01
Hopping (non-preferred leg)	13	(30)	5	(6)	<0.001	52	(21)	50	(10)	<0.001
Ball Balance	20	(45)	5	(6)	<0.001	74	(29)	57	(11)	<0.001

5.9.1.2 Neurological functioning – index children versus comparison children by birthweight groupings

The hypothesis that a higher proportion of both below 1000g and 1000-1499g index children would have impaired neurological functioning, the results of the Quick Neurological Screening Test (QNST) were investigated by analysing the data by birthweight groupings.

For both birthweight groupings a significantly higher proportion of children in both comparison groups were classified as normal.

A higher proportion of index children in both birthweight groupings were classified as suspicious and abnormal – although the number of index children in the abnormal category were very small – especially in the below 1000g group (Table 5.9.1.2).

TABLE 5.9.1.2

Overall performance on the Quick Neurological Screening Test: VLBW and comparison groups by birthweight groupings

	Index		Comparison			Index		Comparison		
	(<1000g)		(A)			(1000-1499g)		(B)		
QNST score	*N*	*(%)*	*N*	*(%)*	*P*	*N*	*(%)*	*N*	*(%)*	*P*
Normal	11	(24)	79	(88)	<0.0005	108	(42)	372	(74)	<0.0001
Suspicious	26	(58)	10	(11)	<0.0001	131	(51)	126	(25)	<0.0001
Abnormal	5	(11)	0	(0)	<0.005*	10	(4)	1	(0.2)	<0.0001
Unable to complete	3	(7)	1	(1)		6	(2)	1	(0.2)	<0.005

**Fisher exact p, one-tailed*

Section 10 Investigation of Gradient Effect by Birthweight Groupings: <1000g, 1000-1499g and ≥1500g

5.10.1 Comparison of score of cognitive ability and educational attainment by birthweight groupings

5.10.1.1 Distribution of IQ by birthweight groupings: <1000g, 1000-1499g and ≥1500g

TABLE 5.10.1.1

Distribution of IQ by birthweight groupings: <1000g, 1000-1499g and ≥1500g (using comparison group norms)

	<1000g (N=44[x]) N (%)	1000-1499g (N=255) N (%)	≥1500g (N=590) N (%)
Mean IQ (SD)	90.4 (11.2)	93.7 (13.6)	101.3 (12.4)
Number of children with IQ: (%)			
≤2 SD below mean - for comparison group	5 (12)	27 (11)	11 (2)
<1 - <2 SD below mean	15 (34)	69 (27)	77 (13)
-1 - +1 SD	23 (52)	146 (57)	404 (68)
≥1SD above mean	1 (2)	13 (5)	98 (17)

[x] One index child unable to complete all the subscales because of profound deafness.

The table above presents mean IQ scores and distribution of IQ in three groupings: index children below 1000g, index children 1000-1499g and all comparison children of 1500g or above. The comparison children were all in fact over 1749g – the original cut off for cohort membership.

The <1000g group scored, on average, three IQ points lower than the 1000-1499 group. The 1000-1499g group in turn scored, on average, eight IQ points lower than the comparison group. While the scores represent a gradient by birthweight it is not statistically significant.

TABLE 5.10.1.1.2

Investigation of a gradient effect by birthweight in differences between mean IQ scores (ANOVA) and Tukey HSD test

Case		(1) mean=90.4	(2) mean=93.7	(3) mean=101.3
<1000g	(1)		0.259	0.000
1000-1499g	(2)	0.259		0.000
≥1500g	(3)	0.000	0.000	

The difference between the mean scores for the 1000-1499g and the ≥1500g group was statistically significant but the difference between the <1000g and the 1000-1499g groups was not. ($\chi 2$ for trend failed to show any significant gradient effect on the groupings of the IQ distribution.)

5.10.1.2 Comparison of composite general, verbal and visual IQ scores by birthweight groupings: <1000g, 1000-1499g and ≥1500g

TABLE 5.10.1.2.1

Mean general, verbal and visual IQs(British Ability Scales) by birthweight grouping: <1000g, 1000-1499g and ≥1500g

	<1000g		*1000g-1499g*		*≥1500g*	
	Mean	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*
General IQ	90.4	(11.1)	93.7	(13.6)	101.3	(12.4)
Verbal IQ	90.6	(10.9)	91.4	(14.4)	97.4	(13.5)
Visual IQ	89.9	(14.9)	96.8	(17.3)	106.4	(15.2)

The mean verbal IQ and visual IQ composite scores are presented in Table 5.10.1.2.1 above. The mean score for verbal IQ were very similar for the two index groups, nevertheless the possibility of a gradient effect was investigated. The differences between the mean scores for visual IQ were more pronounced, making the likelihood of a gradient effect stronger.

TABLE 5.10.1.2.2

Investigation of a gradient effect by birthweight in differences between Mean verbal IQ scores (ANOVA) and Tukey HSD test

		(1)	(2)	(3)
Case		mean=90.6	mean=91.7	mean=97.4
<1000g	(1)		0.938	0.005
1000-1499g	(2)	0.938		0.000
≥1500g	(3)	0.005	0.000	

As expected only the difference between the 1000-1499g group and the comparison group was significant. Therefore, the gradient was not statistically significant.

TABLE 5.10.1.2.3

Investigation of a gradient effect by birthweight in differences between mean visual IQ scores (ANOVA) and Tukey HSD test

		(1)	(2)	(3)
Case		mean=89.9	mean=96.8	mean=106.4
<1000g	(1)		0.021	0.000
1000-1499g	(2)	0.021		0.000
≥1500g	(3)	0.000	0.000	

There was a seven IQ point difference between the mean visual IQ scores for the two index groups. The difference between the 1000-1499g group and the comparison group was 10 points. These differences represent a statistically significant gradient.

5.10.1.3 Comparison of scores of scholastic attainment by birthweight groupings: <1000g, 1000-1499g and ≥1500g

The mean scores for word reading and number skills are presented below for the three groups. The proportion of children performing below the 10th percentile within each group is also presented in the table.

TABLE 5.10.1.3.1

Mean scores and numbers of children functioning below 10th percentile (for the comparison group) on school attainment tasks (British Ability Scales) by birthweight grouping: <1000g, 1000-1499g and ≥1500g

	<1000g		*1000g –1499g*		*≥1500g*	
	Mean	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*
Word reading	47.9	(11.2)	49.9	(11.2)	52.7	(SD 10.9)
N below 10th percentile	12	(26.7%)	50	(19.6%)	67	(11.4%)
Number skills	40.0	(9.1)	45.1	(10.1)	49.1	(SD 10.0)
N below 10th percentile	17	(37.8%)	56	(22.0%)	63	(10.7%)

The mean scores on test of word reading and number skills were investigated for the existence of a gradient effect by birthweight.

TABLE 5.10.1.3.2

Investigation of a gradient effect by birthweight in differences between reading scores (ANOVA) and Tukey HSD test

Case		(1) mean=47.9	(2) mean=49.9	(3) mean=52.7
<1000g	(1)		0.483	0.016
1000-1499g	(2)	0.483		0.004
≥1500g	(3)	0.016	0.004	

As with most of the analyses above there was a statistically significant difference between the 1000-1499g and comparison group but not between the two index groups.

The analysis was repeated for the number skills scores. There was a five point difference between the two index groups and the four point difference between the index and control groups – these differences were statistically significant. Therefore a gradient effect by birthweight was found to exist for number skills.

Investigation of a gradient effect by birthweight in differences between mean number skills scores (ANOVA) and Tukey HSD test

Case		(1) mean=40.0	(2) mean=45.1	(3) mean=49.1
<1000g	(1)		0.005	0.000
1000-1499g	(2)	0.005		0.000
≥1500g	(3)	0.000	0.000	

5.10.2 Neuromotor competence – by birthweight grouping

5.10.2.1 Comparison of performance on Movement Assessment Battery for Children – by birthweight groupings: <1000g, 1000-1499g and ≥1500g

TABLE 5.10.2.1

Numbers (%) of children falling <10th centile for motor skills at eight years of age - by birthweight groupings: <1000g, 1000-1499g and ≥1500g

	(<1000g) N=45		(1000-1499g) N=255		(≥1500g) N=590	
	N	*(%)*	*N*	*(%)*	*N*	*(%)*
Overall Movement ABC score	22	(50)	86	(34)	62	(11)

Fifty percent of the below 1000g index group gained scores which placed them below the 10th percentile. This compares with 34% of the 1000-1499 group and 11% of the comparison group. Thus, there would appear to be a gradient by birthweight in terms of motor competence.

5.10.2.2 Comparison of performance on Quick Neurological Screening Test - by birthweight groupings: <1000g, 1000-1499g and ≥1500g

The proportions of index below 1000g, index children 1000-1499g and comparison children classified as normal, suspicious and abnormal are presented in the table below.

TABLE 5.10.2.2
Overall performance on the Quick Neurological Screening Test - by birthweight groupings: <1000g, 1000-1499g and ≥1500g

	(<1000g)		(1000-1499g)		(≥1500g)		
QNST score	*N*	*(%)*	*N*	*(%)*	*N*	*(%)*	*P*
Normal	11	(24)	108	(42)	451	(76)	
Suspicious	26	(58)	131	(51)	136	(23)	
Abnormal	5	(11)	10	(4)	1	(<1)	
Unable to complete	3	(7)	6	(2)	2	(<1)	

As with the proportion of children performing below the 10th percentile on the Movement ABC, there would appear to be a gradient by birthweight for the QNST. The comparison group had the highest proportion of children classified as normal, the 1000-1499g group had the next highest proportion and only 11 (24%) of the below 1000g children were classified as normal.

There appears to be little by way a gradient as far as the suspicious category is concerned – with 58% of the below 1000g children and 51% of the 1000-1499g children falling within this category.

There does seem to be more of a gradient as far as the abnormal category is concerned but the numbers are very small. It is this fact, indeed, that precludes any formal statistical analysis. The test of choice would be the $\chi 2$ for trend. There are guidelines, however, that state that the results of a Chi Square for trend are meaningless if one of the expected values is less than one and more than 20% of the expected values are less than five. Unfortunately, the guidelines invalidate the analysis for these data.

It is particularly unfortunate that formal statistical analysis is not indicated in the case of either motor competence or neurological functioning. This is so because of the finding above that there is a gradient effect for visual IQ and not for verbal IQ. A hypothesis in this study is that performance on visual IQ is affected by motor competence. It is possible, therefore, that the gradient by birthweight on visual IQ is related to motor competence and does not in fact represent real differences between performance on visual and verbal cognitive functioning. (The reader is referred to Section 12 below and to a discussion of this issue in Chapter 6.)

Section 11 An Investigation of the Importance of Employing Control Groups and Avoiding the use of Outdated Published Test Norms

The distribution of IQ for the index group presented in Section 2 above is based on norms derived from the comparison group. It has been argued that using outdated test norms can result in a considerable underestimation of serious developmental delay and impairment. Table 5.11.1.1 and table 5.12.1.2 below provide a demonstration of the extent of underestimation of severe cognitive impairment when published test norms are used rather than concurrent norms derived from the comparison group.

TABLE 5.11.1.1

Distribution of IQ – index children (<1500g) versus comparison children (using test norms)

	Index Group N=299 [x] N (%)	Comparison Group N=590 N (%)
Mean IQ (SD)	93.2 (13.3)	101.3 (12.4)*
Number of children with IQ: (%)		
≥ 2 SD below mean – for the test	10 (3.4)	4 (0.7)***
>1 – <2 SD below mean	61 (20.4)	55 (9.3)**
1 SD below to 1 SD above the mean	216 (72.2)	449 (76.1)
>1 SD above mean	12 (4.0)	82 (13.9)**

*$p<0.0001$

**χ^2 $p<0.001$

*** $\chi^2 p<0.0001$

[x] One index child unable to complete all the subscales because of profound deafness.

The mean IQ for the comparison group (mean=101.3, SD 12.4) was higher than for the original standardisation sample (mean=100, SD 15), there was also a difference in the variance.

TABLE 5.11.1.2

Distribution of IQ – index children (<1500g) and comparison children (using comparison group norms)

	Index Group N=299 [x] N (%)	Comparison Group N=590 N (%)
Mean IQ (SD)	93.2 (13.3)	101.3 (12.4)*
Number of children with IQ: (%)		
≥ 2 SD below mean - for comparison group	32 (11)	11 (2)**
>1 – <2 SD below mean	84 (28)	77 (13)**
1 SD below to 1 SD above the mean	168 (56)	404 (68)
>1 SD above mean	15 (5)	98 (17)**

*$p<0.0001$

**χ^2 $p<0.0001$

[x] One index child unable to complete all the subscales because of profound deafness.

This demonstrates that by using either published test norms or concurrent norms index children are shown to have higher rates of cognitive impairment. When concurrent norms were employed, however, more than 10% of the index group were found to have serious cognitive impairment, that is, they had IQs more than 2 SD below the mean (for the comparison group). This compares with 3.4% of the index group with IQ scores less than 70 (for the published test norms).

5.11.2 The use of concurrent norms in relation to the distribution of IQ by birthweight groupings

The underestimation of serious cognitive impairment becomes even more pronounced when the index children are considered by birthweight groupings. Table 5.11.2.1 presents the distributions of IQ by birthweight groupings (<1000g and 1000-1499g) for published test norms and Table 5.11.2.2 for concurrent norms derived from the comparison group.

TABLE 5.11.2.1
Distribution of IQ by birthweight groupings – index children and comparison children (using test norms)

	<1000g (N=44ˣ) N (%)	Comparison A (N=90) N (%)	1000-1499g (N=255) N (%)	Comparison B (N=500) N (%)
Mean IQ (SD)	90.4 (11.1)	102.5 (12.4)**	93.7 (13.6)	101.1 (12.4)**
Number of children with IQ: (%)				
≥ 2 SD below mean - for the test	---	2 (2)	10 (4)	2 (0.4)
>1 – <2 SD below mean	12 (27)	6 (7)	49 (19)	49 (10)
1 SD below to 1 SD above the mean	31 (70)	72 (80)	186 (73)	387 (77)
>1 SD above mean	1 (2)	10 (11)	10 (4)	62 (12)*

**$p<0.0001$
*χ^2 $p<0.001$
ˣOne index child unable to complete all the subscales because of profound deafness.

Table 5.11.2.1 demonstrates that no index children in the <1000g group had IQ scores less than 70 for the test norms. When concurrent test norm derived from the comparison group are used, however, six children (representing 14% of the <1000g index group) had IQ scores more than 2 SD below the mean for the comparison group.

TABLE 5.11.2.2
Distribution of IQ by birthweight groupings – index children and comparison children (using comparison group norms)

	<1000g (N=44ˣ) N (%)	Comparison A (N=90) N (%)	1000-1499g (N=255) N (%)	Comparison B (N=500) N (%)
Mean IQ (SD)	90.4 (11.1)	102.5 (12.4)**	93.7 (13.6)	101.1 (12.4)**
Number of children with IQ: (%)				
≥ 2 SD below mean – for the comparison group	6 (14)	3 (3)	27 (11)	9 (2)
>1 – <2 SD below mean	18 (41)	10 (11)	69 (27)	70 (14)
1 SD below to 1 SD above the mean	19 (43)	63 (70)	146 (57)	342 (68)
>1 SD above mean	1 (2)	14 (16)	13 (5)	79 (16)*

**$p<0.0001$
*χ^2 $p<0.001$
ˣOne index child unable to complete all the subscales because of profound deafness.

Many studies reporting on the longer term outcomes of VLBW and very premature infants do not employed control groups – including earlier phases of the Scottish Low Birthweight Study. The implication of the above enquiry into the use of concurrent norms as opposed to published test norms is that those studies that have reported on VLBW groups without employing control groups may well need to reconsider or reevaluate their findings.

This investigation was repeated for measures of scholastic attainment. The results were similar in that the use of concurrent norms identified a higher proportion of children functioning below the 10th percentile in both reading and number. The reader is referred to Appendix 9 for the tables of results for the index group as a whole and by birthweight groupings.

Section 12 Investigation of the Relationship between Motor Competence and Cognitive Ability and Motor Competence and School Attainment

5.12.1 Association between motor competence and performance on the visual processing and verbal processing scales of the BAS.

The results of verbal and visual IQ composite scores presented in Section 2 above demonstrate that there is a greater difference in the mean visual IQ scores (11 IQ points) between the index and comparison groups than in the mean verbal IQ scores (6 IQ points). Some studies have reported finding differences only in the visual processing domain. This is not the case in this study, differences exist in both the verbal and visual domains – only the difference is greater in the latter.

One possible explanation for this difference is that, in general, scales of the BAS that measure aspects of visual cognitive functioning tend to have a greater motor component than those scale that measure verbal processing. It was predicted, therefore, that those index children functioning below the 10th percentile on the Movement ABC would gain lower scores, on average, on tests of visual processing than those children functioning above the 10th percentile. It was predicted that no such differences would exist for the verbal scales of the BAS

As it is possible that children functioning below the 10th percentile in terms of their motor competence might also be of a lower level of general intellectual functioning, general IQ was also taken into consideration in the analyses. Children functioning above or below the 10th percentile on the Movement ABC were considered according to IQ status, that is, IQ falling more than 1 SD below the mean or IQ falling not more than 1 SD below the mean.

Two way ANOVAs were carried out for each of the BAS subscales. The results are summarised below and detailed ANOVA tables and plots of means are presented in Appendix 8.

In order to undertake a comprehensive investigation of this issue, the analyses were repeated for the comparison group. While the hypothesis relates equally to the index and comparison groups, the small numbers in certain categories for the comparison group (just 13 of 590 children performing below the 10th percentile on the Movement ABC and IQ more than 1 SD below the mean) cast doubt on both the homogeneity of variances and on the significance of any differences found.

The ANOVAs and Tukey HSD post hoc tests for the index group demonstrate, as predicted, that motor competence is not associated with performance on any of the scales of verbal processing, including composite verbal IQ. Nor was motor competence associated with performance on the Word Reading or the Basic Number Skills scales.

All ANOVAs and graphs of associated plots of means for the verbal scales and scales of attainments are presented in Appendix 8. As an example the result of the ANOVA for the Word Definitions scale is presented below.

TABLE 5.12.1.1

Differences in mean Word Definitions scores of index children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

IQ status	*Motor status*		(1) mean=34.0	(2) mean=31.6	(3) mean=41.9	(4) mean=41.6
> 1 SD below mean	>10th percentile	(1)		0.677	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.677		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.997
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.997	

As was the case for all the verbal scales and scales of scholastic attainment, for those index children with IQ scores more than 1 SD below the mean, there was no difference in mean Word Definitions scale scores between those with motor impairment and those with satisfactory motor functioning. The same was true for those children with IQ score falling not more than 1 SD below the mean.

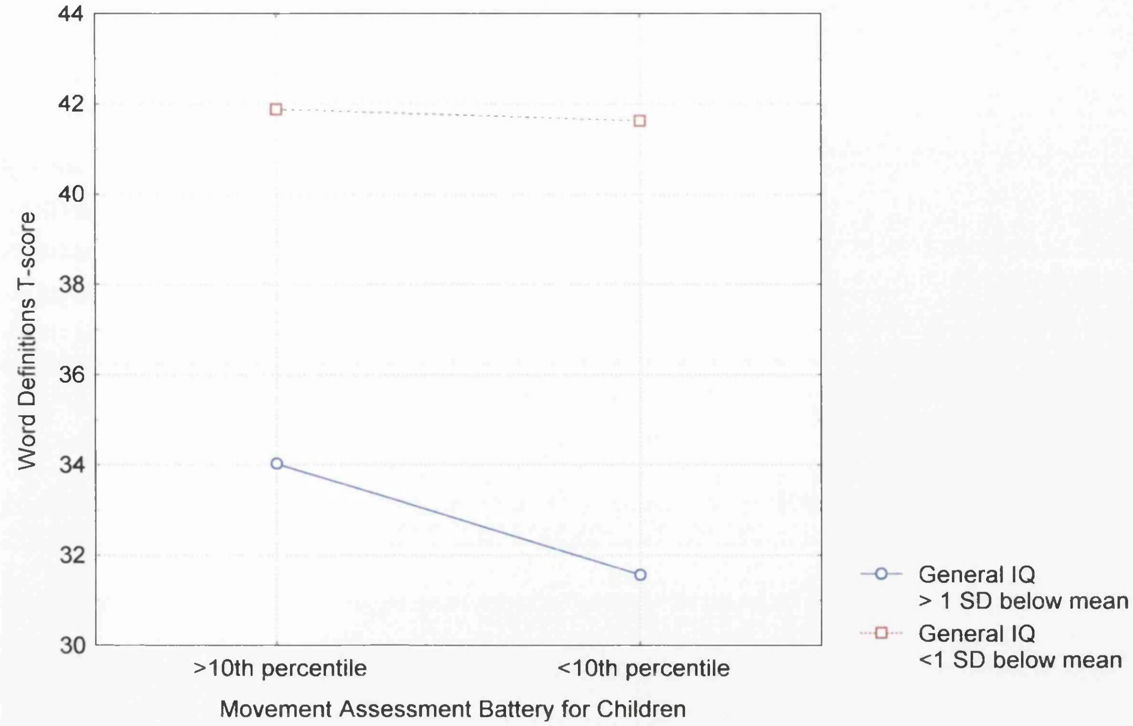

Figure 5.12.1.1 Plot of means (two way interaction) for Word Definitions by motor competence and IQ status (index group)

The prediction that motor competence would be associated with lower scores on the visual scales, namely Recall of Designs, Block Design, Matrices and composite Verbal IQ, was only partially upheld. The ANOVA for Recall of Designs, for example, demonstrates that, at least for those index children of average or above IQ, motor functioning is associated with performance. The mean Recall of Designs score for those of satisfactory intelligence and of satisfactory motor functioning was 54.8 whereas those of satisfactory IQ but poor motor functioning had a mean score of 50.4.

The mean Recall of Designs score for those index children with IQ scores more than 1 SD below the mean and satisfactory motor functioning was 44.8 whereas for those with IQ scores more than 1 SD below the mean poor motor functioning the mean score of 40.8. The difference, however, was not significant.

TABLE 5.12.1.2

Differences in mean Recall of Designs scores of index children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		mean=44.8	mean=40.8	mean=54.8	mean=50.4
> 1 SD below mean	>10th percentile	(1)		0.280	0.000	0.029
> 1 SD below mean	<10th percentile	(2)	0.280		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.004
< 1 SD below mean	<10th percentile	(4)	0.029	0.000	0.004	

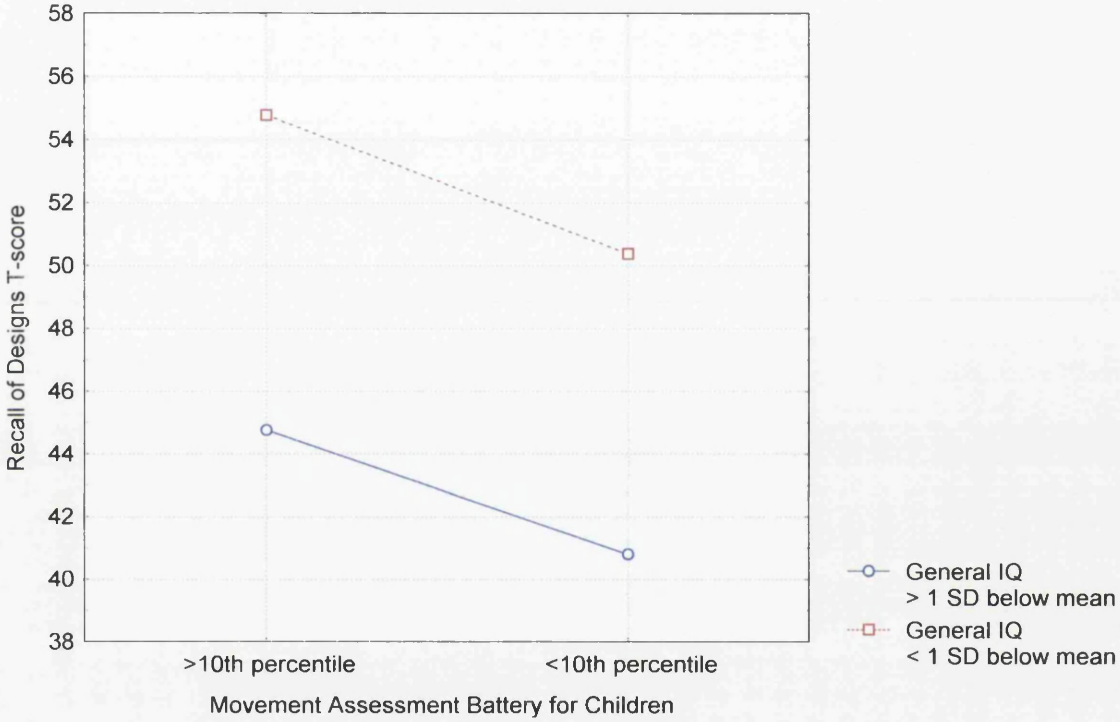

Figure 5.12.1.2 Plot of means (two way interaction) for Recall of Designs by motor competence and IQ status (index group)

The results for the Block Design scale and composite visual IQ were exactly as for Recall of Designs. That is, for those index children of average or above IQ, motor functioning was associated with poorer performance.

The mean Block Designs score for those with IQ scores not more than 1 SD below the mean and satisfactory motor functioning was 51.6 whereas those who had IQ scores not more than 1 SD below the mean and poor motor functioning had a mean score of 47.7. Motor competence was not significantly associated with performance on this scale for those index children of below average intelligence. The direction of the difference was, however, in the predicted direction, mean=39.2 versus mean=35.8.

The mean visual IQ score for those of average or above average intelligence and satisfactory motor functioning was 103.7 whereas those who had below average IQ scores and poor motor functioning had a mean score of 97.8. Motor competence was not significantly associated with composite visual IQ for those index children of below average intelligence. The direction of the difference was, again, however, in the predicted direction, mean=79.4 versus mean=73.7.

Motor competence was not significantly associated with performance on the Matrices scale either for those of below average intelligence or for those of satisfactory intelligence.

The results for the comparison group did not demonstrate any evidence of an association between poor motor functioning and poor performance on any of the scales of the BAS – either verbal or visual. For the comparison group, just as for the index group, motor performance would be expected to be associated with those scales of the BAS that have a motor component. This was not the case, although the results are not unexpected given some of the small numbers involved.

Levene's test for homogeneity of variance was significant for a number of the scales, namely, Similarities, Word Definitions, Verbal IQ, Visual IQ, Word Reading and Basic Number Skills. Had any significant differences been found on any of these scale they could not have been regarded as safe – especially given some of the small numbers concerned.

On the scales of visual processing for the comparison group, the direction of the difference was always in the predicted direction with the single exception of Block Design for those children with IQs more than 1 SD below the mean. Although visual processing scale scores were always lower for those children performing below the 10th percentile on the Movement ABC, with the aforementioned single exception, none of these differences was significant.

5.12.2 Does poor motor functioning ever occur in isolation?

Of the 300 index children in mainstream education in the study 299 were able to complete the Movement ABC, the QNST and the BAS including the tests of reading and number.

Of the 299 children who could be tested on all measures, 27 performed below the 10th percentile on the Movement ABC and had "suspicious" scores on the QNST but were performing in the average range or above in terms of cognitive ability, reading and number. A further three children performed below the 10th percentile on the Movement ABC and had "abnormal" scores on the QNST but were performing in the average or above average ranges in terms of cognitive ability, reading and number.

5.12.3 Movement ABC and Quick Neurological Screening Test in relation to measures of scholastic attainment

The QNST and the Movement ABC both assess neuromotor competence. The QNST, however, purports to detect children with a neurological basis for their learning difficulties by identifying a level of deficit over and above the purely neuromotor aspects of the Movement ABC.

To test this assertion, the performance of the index children on Word Reading and Basic Number Skills was investigated in relation to neuromotor competence (Movement ABC) and neurological status (QNST).

Correcting for motor impairment (using ANOVA), the QNST was still significantly associated with school attainment. Correcting for performance on QNST, however, motor impairment was no longer significantly associated with reading or number skills. This effect is illustrated in Table 5.12.3.1 comparing mean scores in Word Reading and Number Skills for four possible outcomes combining the results of the Movement ABC test and the QNST. The analyses of variance are presented in tables 5.12.3.2 (for number) and 5.12.3.3 (for reading) below.

Table 5.12.3.1

Association between performance on the Quick Neurological Screening Test, Movement ABC and school attainment – index children

	Number skills score		Word Reading score	
QNST score	*mean*	*SD*	*mean*	*SD*
QNST normal and M-ABC >10th percentile (n=90)	47.9	10.2	53.7	10.8
QNST normal and M-ABC <10th percentile (n=29)	49.5	8.6	54.1	8.1
QNST suspicious/abnormal and M-ABC >10th percentile (n=95)	43.5	9.4	47.6	10.9
QNST suspicious/abnormal and M-ABC <10th percentile (n=77)	40.2	9.4	46.3	11.3

Table 5.12.3.2

Association between performance on the Quick Neurological Screening Test, Movement ABC and Number Skills (ANOVA) and Tukey HSD test – index children

		(1)	(2)	(3)	(4)
QNST/Movement ABC status		mean=47.9	mean=49.5	mean=43.5	mean=40.2
QNST normal and M-ABC normal	(1)		0.851	0.011	0.000
QNST normal and M-ABC poor	(2)	0.851		0.017	0.000
QNST poor and M-ABC normal	(3)	0.011	0.017		0.101
QNST poor and M-ABC poor	(4)	0.000	0.000	0.101	

Table 5.12.3.3

Association between performance on the Quick Neurological Screening Test, Movement ABC and Word Reading (ANOVA) and Tukey HSD test – index children

		(1)	(2)	(3)	(4)
QNST/Movement ABC status		mean=53.7	mean=54.1	mean=47.6	mean=46.3
QNST normal and M-ABC normal	(1)		0.997	0.001	0.000
QNST normal and M-ABC poor	(2)	0.997		0.022	0.005
QNST poor and M-ABC normal	(3)	0.001	0.022		0.867
QNST poor and M-ABC poor	(4)	0.000	0.005	0.867	

Thus, conditional on QNST performance, index children with or without motor impairment do not, on average, differ with respect to school attainment.

As the QNST is designed to identify children with a neurological basis for their learning difficulties is should do so irrespective of the case status of the children. In other words whether or not children were born at very low birthweight, if they are classified as “suspicious” or “abnormal” on the QNST they would be expected to gain lower scores on measures of scholastic attainment than those children who are classified as “normal”. Again this is based on the assumption that the QNST is identifying a level of deficit over and above the purely neuromotor aspects of the Movement ABC

The performance of all children (index and comparison children together) on Word Reading and Basic Number Skills was investigated in relation to neuromotor competence (Movement ABC) and neurological status (QNST).

As for the index children alone, when all children were taken together the QNST was significantly associated with school attainment. Correcting for performance on QNST, however, motor impairment was not significantly associated with reading or number skills. This is illustrated in Table 5.12.3.4 comparing mean scores for index and comparison children taken together in Word Reading and Number Skills for four possible outcomes combining the results of the Movement ABC test and the QNST. The analyses of variance are presented in tables 5.12.3.5 (for number) and 5.12.3.6 (for reading) below.

Table 5.12.3.4

Association between performance on the Quick Neurological Screening Test, Movement ABC and school attainment – index and comparison children together

	Number skills score		Word Reading score	
QNST score	*mean*	*SD*	*mean*	*SD*
QNST normal and M-ABC >10th percentile (n=510)	49.5	9.87	53.8	10.8
QNST normal and M-ABC <10th percentile (n=59)	50.3	9.62	53.2	8.6
QNST suspicious/abnormal and M-ABC >10th percentile (n=200)	44.9	9.94	48.5	10.8
QNST suspicious/abnormal and M-ABC <10th percentile (n=109)	42.2	10.17	47.1	11.4

Table 5.12.3.5

Association between performance on the Quick Neurological Screening Test, Movement ABC and Number Skills (ANOVA) and Tukey HSD test – index and comparison children together

		(1)	(2)	(3)	(4)
QNST/Movement ABC status		mean=49.5	mean=50.2	mean=44.9	mean=42.2
QNST normal and M-ABC normal	(1)		0.953	0.000	0.000
QNST normal and M-ABC poor	(2)	0.953		0.002	0.000
QNST poor and M-ABC normal	(3)	0.000	0.002		0.106
QNST poor and M-ABC poor	(4)	0.000	0.000	0.106	

Table 5.12.3.6

Association between performance on the Quick Neurological Screening Test, Movement ABC and Word Reading (ANOVA) and Tukey HSD test – index and comparison children together

		(1)	(2)	(3)	(4)
QNST/Movement ABC status		mean=53.8	mean=53.2	mean=48.5	mean=47.1
QNST normal and M-ABC normal	(1)		0.975	0.000	0.000
QNST normal and M-ABC poor	(2)	0.975		0.017	0.002
QNST poor and M-ABC normal	(3)	0.000	0.017		0.658
QNST poor and M-ABC poor	(4)	0.000	0.002	0.658	

Once again, conditional on QNST performance, children (irrespective of case status) with or without motor impairment do not, on average, differ with respect to school attainment. The box and whisker plots below graphically illustrate this effect.

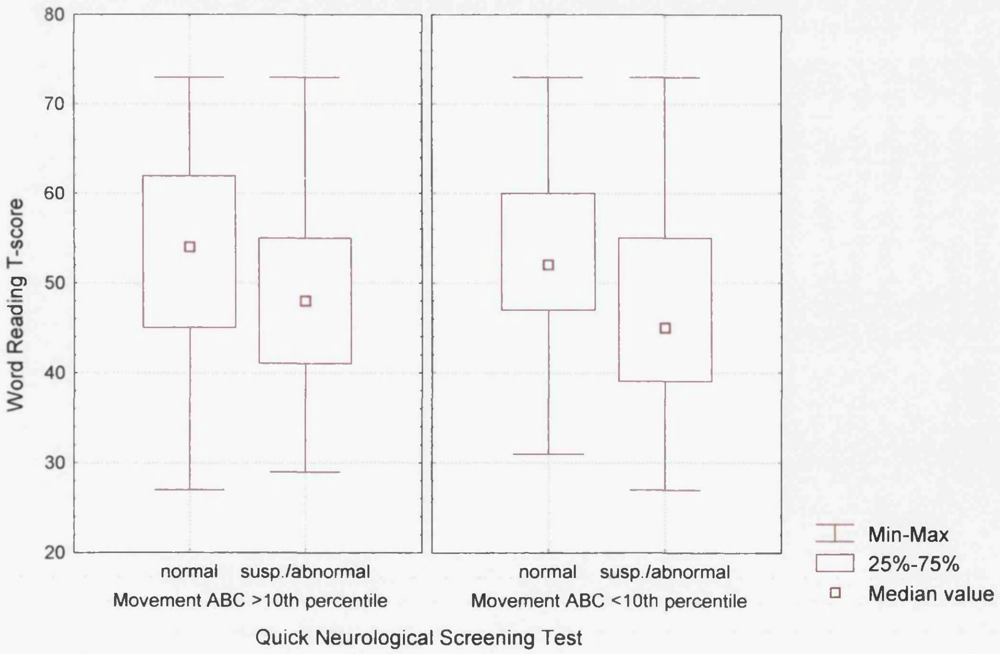

Figure 5.12.3.1 Categorised box and whisker plot for Word Reading scale by QNST and Movement ABC (all children – index and comparison)

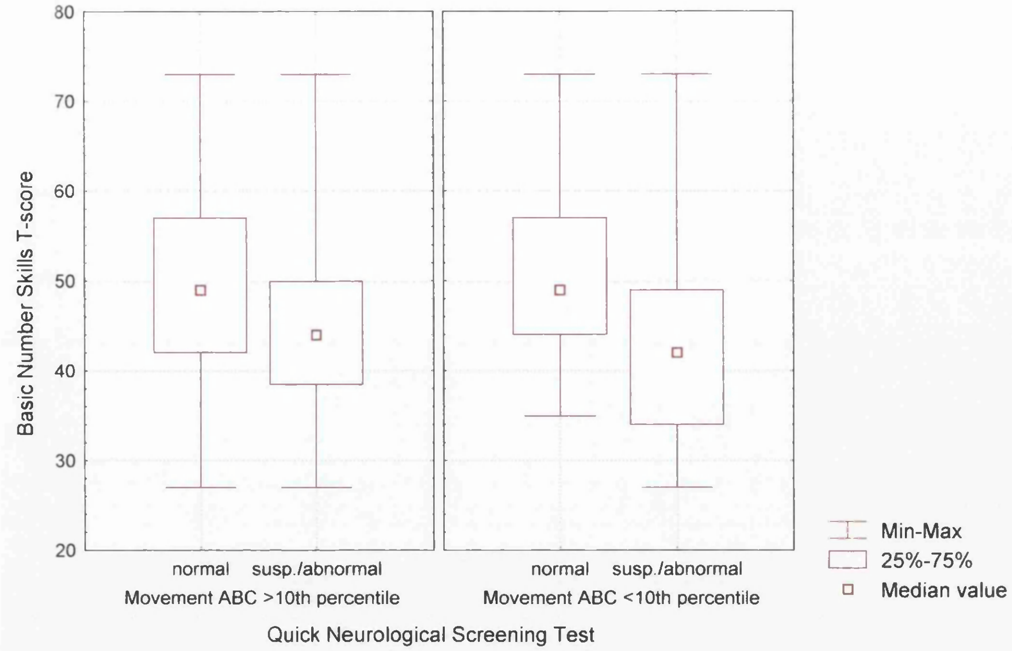

Figure 5.12.3.2 Categorised box and whisker plot for Basic Number Skills scale by QNST and Movement ABC (all children – index and comparison)

Section 13 Performance of index children in special schools

The children who belong to the cohort of VLBW children who are being taught in special educational provision are reported on below. The methodological reasons for not including these children in the analyses above has been outlined in Chapter 3 and is discussed again in Chapter 6.

Of the 324 children that comprised the index cohort in the eight year follow up of the Scottish Low Birthweight Study, 24 were being educated in the special school sector. Half of these children were unable to participate in the neuromotor assessment, either because of severe motor disability, severe visual impairment or inability to understand what was being asked of them. Of the 12 who were tested using the Movement ABC test, five could not complete all the tasks, six performed below the 10th percentile and one was classified as normal. The performance of this child on the QNST, however, was classified as "suspicious" and his IQ was 77.

The same 12 children were able to participate in at least some elements of the QNST, but five of them failed to complete it. Six children had abnormal or suspicious scores and one had a score classified as normal. The child with the score classified as normal on the QNST had an IQ of 87, but he performed below the 10th percentile on the Movement ABC test.

Of the 12 children in special schools only eight were able to attempt any of the subscales of the BAS; of those only eight were able to complete a sufficient number of the scales to permit the allocation of an IQ score. Five of these children had IQs less than 70, two had IQs between 70 and 84 and one had an IQ in the normal range of 85 to115.

The New Survivors: The longer term cognitive, scholastic and motor outcomes of a total Scottish population of surviving very low birthweight infants

Volume 2

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November, 2000

Chapter Six - The Scottish Low Birthweight Study (Eight Year Follow Up) – Discussion

> The human brain is a living, growing , changing organ. It can even carry out its own repairs to some extent. But it is bound by the inexorable evolution of its functional aptitudes, and no one can alter this, not even an educator or a psychiatrist. One can draw up a functional timetable for the brain of a child. One might well say there is a built-in biological clock that tells the passing time of educational opportunity.
>
> Wilder Penfield

6.1 General summary

The present study, representing the eight to nine year follow up of the Scottish Low Birthweight Study, has investigated the cognitive, scholastic, motor and neurological development of VLBW children in comparison to their heavier birthweight classroom peers. At eight to nine years of age the index children have been shown to be distinguishable from their matched classroom peers in every sphere of activity investigated.

6.2 Interobserver variation

The presence of interobserver variation in the data has been explored and reported (Chapter 4). It is acknowledged that the estimates of the prevalence of problems, both cognitive (BAS) and rates of neurological problems (QNST), may be underestimated due to the presence of observer bias. It is important to emphasise, however, that this observer bias was constant for both the index and comparison groups. The comparison between the index children and their classroom peers – the main focus of this study- should not affected.

6.3 Index children in special education

6.3.1 Methodological considerations

The review of methodological issues in this thesis (Chapter 3) considered the issue of including severely impaired children in data analysis. It has been recommended that VLBW follow-up studies should uniformly exclude such children from analyses of continuous data in order to avoid presenting an inaccurate picture of outcome (e.g. Keily and Paneth, 1981). That is, if data for VLBW children who have major neuropathology are analysed and reported on together with the rest of the data, an artificial lowering of the mean scores for the total population is likely to result.

It is important, however, that severely impaired children should be reported upon elsewhere in the study. Frequencies of impairments and disabilities should be reported together with the results of any parts or sub-sections of standardised tests which were successfully administered. Of the studies reviewed in this thesis (Chapter 2) only between 25% and 30% excluded severely impaired children from their analyses of continuous data and, furthermore, many of these studies failed to distinguish between the terms impairment, disability and handicap. As discussed in

Chapter 3, World Health Organisation conventions have existed since 1980 regarding operational definitions of these terms. Nevertheless, the review of the studies reported in this thesis found that the terms impairment, disability and handicap were often used synonymously.

6.3.2 Performance of index children in special schools

A largely qualitative account of the performance of the index children being taught in the special education sector is presented in Chapter 5. In summary, 24 of 324 surviving VLBW children were being educated in the special school sector. Severe motor disability, severe visual impairment or inability to understand what was being asked of them prevented half of these children participating in neuromotor assessment (Movement ABC). Of the remaining 12 children, only one was classified as normal, six were performing below the 10th percentile and five could not complete all elements of the test.

The same 12 children were able to participate in at least some elements of the QNST. Again one child was classified as normal (not the same child that passed the Movement ABC) six had abnormal or suspicious scores and five children failed to complete all elements of the test.

Only eight of 12 children who attempted the BAS were able to complete a sufficient number of the scales to permit the allocation of an IQ score. Five of these children had IQs less than 70, two had IQs between 70 and 84 and one had an IQ in the normal range of 85 to115.

6.3.3 The identification of appropriate matched controls for index children in special education

At the outset of this study it had been the intention to identify two matched control children for every index child in special education. The same procedure was followed as for children in mainstream education. That is, the headteacher was asked to identify the two children being taught in the same class, of the same gender and nearest in date of birth to the index child.

Early on it became apparent that the comparison children being identified in this way were not appropriate controls. By way of example, of the two comparison children identified in one special school by the headteacher one had the fragile X chromosome (with associated behavioural difficulties) and the other had childhood autism (with whom any kind of interaction was difficult). A decision was taken, therefore, early in the data collection phase of the study that children in special schools would be visited and assessed but without comparison children. It was also decided that the results of the assessments of these children would not form a part of the main analyses but would be reported on separately. (The reader is referred to Chapter 5.)

The remaining sections of this chapter relate only to those children who were being educated in mainstream school - for whom appropriate matched controls were available.

6.4 Cognitive abilities

Compared with classroom peers of the same age and gender, index children gained on average significantly lower IQ scores. The distribution of IQ scores shows a downward shift for the index children. A significantly greater proportion of the index group was found to be functioning more than 2 SD below the mean for the comparison group. Furthermore, a significantly greater proportion of the index group was found to be functioning between 1 SD and 2 SD below the mean for the comparison group.

6.4.1 Importance of employing control groups and avoiding the use of outdated published test norms

The distribution of IQ presented in Chapter 5 is based on norms derived from the comparison group. It has been argued that using outdated test norms can result in a considerable underestimation of serious developmental delay and impairment (Bill, Sykes, Hoy, 1986; Wolke et al., 1994). It has also been asserted that studies employing matched comparison groups tend to show greater differences in cognitive and motor functioning than studies using published norms e.g. Abel Smith & Knight-Jones, 1990.

Wolke et al. (1994) demonstrated that by using concurrent test norms derived from full term comparison children and a representative sample from the same birth cohort, more than two times as many very premature infants were identified as seriously impaired than when the published test norms were employed.

In this phase of the Scottish Low Birthweight Study the published test norms, at the time of testing, were over 10 years old. As in the study by Wolke et al. the mean IQ for the comparison group (mean=101.3, SD 12.4) was higher than for the original standardisation sample (mean=100, SD 15). Table 5.11.1.1 and table 5.11.1.2 provide a demonstration of the extent of underestimation of severe cognitive impairment when published test norms are used rather than concurrent norms derived from the comparison group.

The index children were shown to have higher rates of cognitive impairment when either published test norms or concurrent norms were used. When concurrent norms were employed, however, more than 10% of the index group were found to have serious cognitive impairment, that is, they had IQs more than 2 SD below the mean (for the comparison group). This contrasts with 3.4% of the index group with IQ scores less than 70 (using the published test norms).

Less than 25% of the index group had IQ scores less than 85 using the published test norms but almost 30% had IQ scores more than 1 SD below the mean for the comparison group.

It is noteworthy that 76% of the comparison group had IQs in the range 85-115 using the published test norms. This is a higher proportion than would be expected to fall within + or – 1 SD of the mean.

6.4.2 The use of concurrent norms in relation to the distribution of IQ by birthweight groupings

Considering the index group by birthweight groupings (<1000g and 1000-1499g) the mean IQ scores of both groups were significantly lower than those of their respective comparison groups 90.4 vs. 102.5 (<1000g) and 93.7 vs. 101.1 (1000-1499g)

The underestimation of serious cognitive impairment arising from the use of published test norms, however, becomes even more pronounced when the index children are considered by birthweight groupings. Table 5.11.2.1 presents the distributions of IQ by birthweight groupings (<1000g and 1000-1499g) using published test norms and Table 5.11.2.2 using concurrent norms derived from the comparison group.

Table 5.11.2.1 demonstrates that no index children in the <1000g group had IQ scores less than 70 using the test norms. When concurrent test norm derived from the comparison group are used, however, six children (representing 14% of the <1000g index group) had IQ scores more than 2 SD below the mean.

Approximately 25% of the <1000g index group had IQ scores less than 85. This compares with more than 50% of this group who had IQ scores more than 1 SD below the mean for the comparison group. Again a disproportionate number of comparison children had IQ scores between 85 and 115 (80% for comparison group A and 77% for comparison group B) when published test norms were employed.

There are many studies reporting on the longer term outcomes of VLBW and very premature infants that have not employed control groups – including earlier phases of the Scottish Low Birthweight Study (which had double the number of index children). The implication of the above enquiry into the use of concurrent norms rather than published test norms is that those studies that have reported upon the cognitive ability of VLBW groups without employing control groups may well have provided underestimates of the number of children considered impaired. Ideally the findings of such studies should be reevaluated. At the very least the appropriateness of the test norms to the index group could be reported, especially in terms of how current they are.

6.4.3 The use of concurrent norms in relation to the proportion of index children functioning below 10th percentile on measures of scholastic attainment

This study is concerned not only with the cognitive development of the index children but also with scholastic progress. Tests of number and reading were presented as part of the test protocol. Mean scores for the index and comparison groups were compared and the proportion of children performing below the 10th percentile was reported.

An investigation similar to that performed to explore the possible underestimation of the rate of serious cognitive impairment arising from the use of published test norms was carried out in relation to the proportion of index children functioning below 10th percentile on tests of reading and number (Appendix 9).

The mean Word Reading score for the index group was 49.6 (SD 11.2) and the mean score for the comparison group was 52.7 (SD 10.9). Using published test norms 44 index children (14.7%) fell below the 10th percentile. This contrasts with 62 children (20.7%) who were performing below the 10th percentile for the comparison children.

The pattern is similar for Number Skills. The mean score for the index group was 44.3 (SD 10.1) and the mean score for the comparison group was 49.1 (SD 10.0). Using norms for the test 62, children (20.7%) were performing below the 10th percentile as compared with 75 children (25%) when using norms derived from the comparison group.

Thus, just as the use of published test norms failed to capture the true rate of cognitive impairment, so the use of test norms resulted in an underestimation of the proportion of children performing below the 10th percentile on measures of both reading and number.

Reference to table 5.11.4.1 and table 5.11.4.2 demonstrates that when the index group is considered according to birthweight groupings (<1000g and 1000-1499g) the proportion of children performing below the 10th percentile on measures of reading and number is always underestimated when published test norms area used – with the single exception of number skills for the <1000g index group where there was no difference when either test norms or norms derived from the comparison group were used.

In summary, in this phase of the Scottish Low Birthweight Study significant differences were found between the index and comparison children on measures of general IQ, reading and number – both in terms of differences in mean scores and in terms of the proportion of children with serious impairment. This was the case whether published test norms were used or norms derived from the comparison group. The extent of the rates of serious impairment is less accurately captured, however, when published test norms are employed.

Again it is suggested that those many studies that did not employ a control group and used published test norms should consider the appropriateness of these norms to their index groups.

6.5 Consistency in the findings from this study and other large scales controlled studies of VLBW or very premature children

The findings of this study, in relation to cognitive ability and scholastic attainment, are consistent with most other large scale controlled studies (e.g. Botting et al., 1998; Pharoah et al., 1994a; Saigal, et al., 2000; Wolke &Meyer, 1999; Stjernqvist & Svenningsen, 1999; Horwood et al., 1998; Jongmans et al., 1998).

6.5.1 Shortcomings in the coverage of the literature in the reports of a small number of other study groups

The New Zealand study (Horwood et al., 1998) reported similar findings to the present study. The authors, however, asserted that their study was the only complete national cohort study that had employed a control group at school age follow up. While their report did refer to the Scottish Low Birthweight Study, the authors failed to acknowledge the eight year follow up (Hall et al., 1995) – the first follow up from this study to employ a control group. This oversight was acknowledged and rectified shortly thereafter (Horwood et al., 1999). As it turns out, not only did the present study employ a control group at the eight year follow up, it was more methodologically sound than the New Zealand study. Horwood et al. employed historical controls, the comparison children in the present study were matched by age, gender and classroom environment.

The recent report from the southern Swedish study (Stjernqvist & Svenningsen, 1999) suggested that theirs is one of the few school age follow up studies to report upon an extremely premature cohort after not less than three years of compulsory education.

The authors suggest that it is important to assess these children after they have been in compulsory education for a few years as they will, by then, have recovered from the transition from pre school educational arrangements - characterised by more lenient behavioural demands and less in the way of structured activities. They assume that, as the children will have become familiar with their teachers, schoolmates and the school environment, they will be able to perform optimally. Although the authors do not mention it, this will presumably apply equally to the children in any comparison group that is recruited.

The authors go on to cite a number of studies as having reported upon their cohorts after just one or two years of compulsory schooling, including the Scottish Low Birthweight Study. While these authors do cite the eight year follow up of the Scottish Low Birthweight Study, they fail to appreciate that the Scottish children had completed three full years and were into their fourth year of primary education. It may be that the authors have failed to appreciate that there is considerable variation across countries in terms of the age at which compulsory education commences. Compulsory education in Scotland and, indeed, the UK commences earlier than in most other countries. Children must have commenced education by five years of age, although many actually start school while still four years of age.

6.6 Cognitive abilities – performance on BAS subscales

The scores of the index group on all but one of the cognitive scales of the BAS were lower than the comparison group. As predicted the exception was Recall of Digits - a test of short term auditory sequential memory. This is a similar pattern of results to that found by Michelsson et al. (1984) in Helsinki, by Jongmans et al. (1998) in London and, indeed, in the four year follow up in this study (Scottish Low Birthweight Study Group, 1992b). The test instruments used by Michelsson et al. differed from those employed in the present study (Wechsler Intelligence Scale for Children (WISC) and the Illinois Test of Psycholinguistic Abilities (ITPA) but Jongmans et al. did use the BAS as their measure of cognitive ability. Other studies have, however, found differences between VLBW/very preterm children and comparison children on measures of short term auditory sequential memory e.g., Lloyd et al. and Fritsch et al. Both of these studies were relatively small controlled studies. The study by Lloyd et al. comprised 45 matched index and comparison pairs, and the BAS was used as the instrument for measuring cognitive abilities. Apart from a statistically significant difference in mean general IQ scores between the two groups the only other scale where a significant difference was found was Recall of Digits. A significant difference was also found on the one attainment scale that was administered, namely, Word Reading. These results differ from those in the present phase of the Scottish Low Birthweight Study. While both studies found no difference between performance on verbal and visual subscales, the only area of intact functioning, on average, in the present study, namely, Recall of Digits was the only area of weakness in the Lloyd et al. study.

6.6.1 Is VLBW associated with dyslexia/specific learning difficulties

In terms of the relationship of VLBW/very preterm birth research and educational practice, it is of considerable importance that the different findings reported by Lloyd et al. and the present study be resolved.

The findings of the Lloyd et al. study imply that VLBW children tend to experience dyslexia/specific learning difficulties once they have embarked upon formal education. There are two main criteria that underpin a diagnosis of dyslexia. Firstly, it is widely accepted that there should be a significant discrepancy between general conceptual ability (general IQ) and attainment in reading and/or written language. (As far as written language is concerned, the focus is usually on spelling although the overall organisation of the written output of the dyslexic child is often faulty.) Secondly, there should exist a recognised pattern of cognitive strengths and weaknesses. This second diagnostic criterion is important as poor or delayed acquisition of basic literacy skills could be due to a range of factors such as poor motivation or extensive absence from school as a result of ill health. There are a number of recognised patterns of cognitive strength and weakness that are associated with dyslexia/specific learning difficulties. The most common of these is where the cognitive profile is characterised by satisfactory functioning across all cognitive subskills with the exception of short term auditory sequential memory – which is weaker. (Other patterns include specific weakness in visual perceptual skills and specific difficulty in retrieving and applying knowledge from long term memory.)

The findings of the Lloyd et al. study indicate that the index children in their study tend to fulfil the diagnostic criteria for dyslexia/specific learning difficulties. The findings reported in this study do not support the notion that the index children tend to experience dyslexia/specific learning difficulties – quite the reverse. The pattern of cognitive strengths and weaknesses reported by Lloyd et al. is inverted in the present study. That is, the overall profile of cognitive skills is depressed, with the exception of short term auditory memory, which is preserved. Moreover, on the tests of attainment in the present study, the mean score of the index group on Word Reading was very close to the mean score for the test – although the comparison group did gain, on average, significantly higher Word Reading scores. Nevertheless, the present study did not find that the index group were underachieving in terms of their basic reading skills. (The issue of underachievement is discussed in detail below.)

6.6.2 The provision of additional resources for children with particular educational needs

The reason why it is so important to resolve which set of findings represents a truer reflection of the VLBW population relates to the main aim of research of this kind, that is, that research findings should be translated into practice. On the basis of findings such as those reported by Lloyd et al., education administrators might well be persuaded to target additional resources towards VLBW children in order to intervene early on their behalf in an attempt to ameliorate their difficulties in acquiring satisfactory literacy skills. Doing so on the basis of erroneous research findings should do no harm to the children concerned but it is an inefficient use of resources.

The study by Lloyd et al. is a controlled study of a geographically defined population of VLBW children. It is, however, a small study and nearly all of the index children were referred to the neonatal intensive care unit of a single Wolverhampton hospital. The Scottish Low Birthweight study is, at the eight year follow up, a controlled study. It comprises a nationwide cohort of VLBW survivors numbering over 300 children. Furthermore, the findings of the present study almost exactly reflect those of the Hammersmith study (Jongmans et al., 1998) which also used the BAS. It also reflects, in a more general way, the commonly reported pattern of poorer levels of functioning across all outcome measures – as opposed to specific areas of difficulty. Arguably, there is a greater likelihood that the results of the present study are more accurate than those of Lloyd et al. and that it would, therefore, be inadvisable to recommend to education administrators that additional resources be directed towards this group on the basis that they are likely to develop dyslexia/specific learning difficulties. This is not to say that this group of children is not a needy group educationally speaking, only that their particular needs are not characterised by specific difficulties but by more general difficulties across all areas of functioning. As a result, directing additional educational resources toward this group may be appropriate, but it is necessary to consider the reason why such resources are being provided, to what use they are to be put and how the effectiveness of such additional resources can be evaluated. (This issue is revisited below.)

6.6.2.1 Importance of achieving 100% follow up or documenting the dropouts

A methodological issue that relates to the identification and support of needy children is that of achieving complete follow up or documenting those who have dropped out from studies. A number of studies have demonstrated that failure to achieve a 100% follow up rate or, as a second best, documenting the characteristics of those who have dropped out, is likely to lead to an under reporting of the developmental sequelae of preterm/VLBW birth (Aylward, Hatcher, Stripp, Gustfson, Leavitt, 1985; Wariyar, Richmond, 1989; Wolke et al., 1995). Wolke et al. suggest that it is those parents who have been unable to come to terms with their children's impairment and handicaps who are most likely to refuse to participate in follow up studies – as it highlights the difficulties their children are experiencing. From those studies that have documented those who have dropped out, it does seem to be those infants and children with more serious developmental sequelae who tend to be lost.

Wolke et al. make the additional observation that it tends to be mothers with lowest levels of educational attainment and their infants who are the most difficult to retain in follow up studies. This is particularly unfortunate as it is these children who are probably the most needy and who would most benefit from additional provision and intervention - yet they are unlikely to be targeted as they have opted out of both the longitudinal study and surveillance by community paediatric services. This, in turn, suggests that these parents will not have presented their children for routine pre school assessment. Such assessments, although carried out by medical officers and school nurses, involve not only physical assessments but also tests of early language and conceptual development. Information from such assessments can be passed on to the receiving school in order that the staff can prepare a system of monitoring and/or early intervention. Clearly, if these children have not undergone routine pre school assessment there is no way in which the staff of the receiving school can be forewarned of their potential educational needs.

6.6.3 The association between short term auditory memory and reading ability

The clinical experience of educational psychologists suggests that specific weakness in short term auditory memory is associated with literacy difficulties. The results of this study would appear to be the other side of the coin. That is, the one cognitive sub skill that is spared is Recall of Digits and Word Reading scores are also relatively well preserved.

However, where the Recall of Digits T-score was less than 40 (more than 1 SD below the mean) and general IQ was equal to or greater than 85 (not more than 1 SD below the mean) the mean Word Reading score of the index group was 48.2. Where the Recall of Digits T-score was greater than or equal to 40 and general IQ was greater than or equal to 85 the mean Word Reading score of the index group was 52.8. This would seem to indicate that short term auditory sequential memory is indeed a cognitive sub skill that is implicated in the acquisition of basic literacy skills.

If it is the case that there is an association between short term auditory sequential memory and the acquisition of literacy skills then a similar pattern would also be expected for the comparison group. The mean Word Reading score of the comparison group where the Recall of Digits T-score was less than 40 and general IQ was greater than or equal to 85 was 48.0. The mean Word Reading score of the comparison group where the Recall of Digits T-score was greater than or equal to 40 and general IQ was greater than or equal to 85 was 54.6. Thus the pattern does hold true for the comparison group also.

The relationship between performance on the Recall of Digits scale of the BAS and Word Reading, taking into consideration level of general IQ, was investigated using ANOVA for both the index and comparison groups. Full details of the results and plots of means are presented in Appendix 10. The difference in Word Reading scores for comparison children of satisfactory intelligence with Recall of digits scores below

40 and with Recall of Digits scores equal to or above 40 was significant. The difference in Word Reading scores for comparison children of below average intelligence was in the predicted direction but was not significant. Neither were the differences in Word Reading Scores significant for the index children irrespective of level of general IQ – although again the differences were in the expected direction. The significance of all of the above comparisons were tested using the Tukey HSD post hoc test. As mentioned above, this is a stringent test of significance but it is the appropriate test to use in this investigation because of the unequal numbers involved. It is perhaps, noteworthy, that a less stringent test such as the LSD test would have elicited significant differences for all comparisons.

Thus the relationship between Recall of Digits and Word Reading is significant for comparison children of satisfactory general ability and, while nothing definitive in this regard can be said for the other groups, there are indications that the relationship may also apply to comparison children of below average ability and to index children of below or above general ability.

Whether or not there is a relationship between short term auditory memory and reading, the fact remains that the index children in this study performed relatively well on the Word Reading scale. Within the wider context of school education this is encouraging for VLBW children as reading is a skill that allows for independence in learning, that is, independent access to a curriculum. Intact reading skills go a long way to enabling children to achieve their academic potential. (It is the converse of severe dyslexia where there is an inability to access a curriculum independently and reliance on the support of others if academic potential is to be achieved.)

Should it turn out that the relationship between short term auditory memory and reading holds true not only for the comparison children of satisfactory intelligence but also more widely, this would suggest that it is verbal/auditory strategies that are of greater importance in the acquisition of reading skills. This, in turn, would imply that those involved in the teaching of reading to these children should perhaps focus on a phonological approach, as suggested by the work of Bradley and Bryant, 1983. Commonly used visual approaches such as "look and say" should, on the other hand, be de-emphasised. Even although this study has not been able to show a clear association between short term auditory memory and reading for the index children, the fact remains that the only intact cognitive subskill in this group was Recall of Digits, none of the visual subskills were spared. There would seem to be sense, therefore, in avoiding teaching strategies that place a heavy reliance on visual processing.

6.7 To what extent are the British Ability Scales valid measures of discrete areas of cognitive functioning?

The individual subtests of the British Ability Scales purport to measure discrete areas of cognitive functioning but it is not clear that they do so in every case. It seems likely that at least some scales are contaminated by confounding factors. The Recall of Digits tests purports to measure short term auditory sequential memory and it is unlikely that there are any confounding factors operating on this sub scale. (Although children with attention control problems are likely to have difficulty with short term auditory memory tasks and boredom will affect performance on any activity.) The same is probably true for Word Definitions and Similarities although while the latter purports to measures verbal reasoning skills it must also, to some extent, place a demand upon retrieval of information from long term memory and on short term auditory memory.

In the case of scales such as Recall of Designs (which purports to measure short term visual memory) and Block Design (which purports to measure spatial visualisation) there is very clearly a demand being placed on fine motor skills that could be confounding the results. This study has shown that neuromotor impairment is more common in the index group. It may be the case, therefore, that there are other cognitive sub skills that are less impaired in the index group than would appear to be the case.

Scores on all scales of the BAS were investigated to discover the extent to which motor competence affects performance. The verbal scales, where motor competence is unlikely to affect performance, were analysed initially (Chapter 5, section 12). It is also possible that level of general intellectual functioning will affect performance, therefore, children of below average general intellectual ability were separated out from those of average or above, general intellectual ability in the analyses.

Table 5.12.1 demonstrates that motor status does not have any bearing on performance on the Word Definitions scale. For those children with IQ scores more than 1 SD below the mean, there is no difference in mean Word Definitions scale scores between those with motor impairment and those with satisfactory motor functioning. The same is true also for those children with IQ score falling not more than 1 SD below the mean.

The same analysis was carried out for Similarities, Recall of Digits, Speed of Information Processing and composite Verbal IQ. For all four scales motor competence did not affect performance – irrespective of IQ status.

A scale of the BAS where motor functioning might be expected to affect performance is Recall of Designs. As explained above the aim of this test is to assess short term visual memory, but the child is required to reproduce the memorised designs using paper and pencil.

Table 5.12.2 shows that, at least for those index children with IQ scores not more than 1 SD below the mean, motor functioning affects performance. The mean Recall of Designs score of those index children of satisfactory intelligence and of satisfactory motor functioning was 54.8 whereas those of satisfactory IQ but poor motor functioning had a mean score of 50.4 – the difference being statistically significant. The mean Recall of Designs score for those index children with IQ scores more than 1 SD below the mean and satisfactory motor functioning was 44.8 whereas for those with IQ scores more than 1 SD below the mean poor motor functioning the mean score of 40.8. The difference, however, was not significant.

An investigation of the other BAS scales where motor competence might be expected to affect performance, namely, Block Design, Matrices and composite Visual IQ was carried out. The results for Block Design and composite Visual IQ were exactly as for Recall of Designs. That is, for those index children of average or above IQ, motor functioning is associated with poorer performance. The mean Block Designs score of those with satisfactory intelligence and satisfactory motor functioning was 51.6 whereas those of satisfactory IQ but poor motor functioning had a mean score of 47.7. Motor competence was not associated with performance on this scale for those index children of below average intelligence.

Motor competence was not significantly associated with performance on the Matrices scale either for those of below average intelligence or for those of satisfactory intelligence.

It is important to acknowledge therefore that, at least for children of satisfactory general intellectual ability, performance on some measures of cognitive functioning can be adversely affected by poor motor competence. This applies most of all to visual scales which tend to place a larger demand on motor skills than do verbal scales. The same is likely to be true of other cognitive assessment batteries such as the Kaufmann ABC and the WISC-R. This argument would not, however, be considered relevant to tests of visual motor integration such as the Beery test or the Bender Gestalt test as motor functioning is an integral part of the skill being assessed.

6.8 Performance in basic literacy and numeracy skills

On the two tests of scholastic attainment the index group performed less well than the comparison group, number being poorer than reading. The finding that the acquisition of number skills is a particular area of difficulty has been reported in other studies (e.g., Klein et al., 1989; Botting et al., 1998). Klein et al. reported that their index children scored significantly lower than full term control children on a test of academic achievement, with differences in maths being greater than differences in reading. In their subset of index children of normal IQ, VLBW was associated with a delay in maths only. The small differences in reading scores were not significant. Klein et al. reported that the difference in maths scores between index children and comparison children persisted after controlling for IQ.

Both the 8 year follow up (Marlow et al., 1993) and the 12 year follow up (Botting, et al., 1998) of the Liverpool Maternity Hospital study found that the test of mathematics elicited the greatest difference between the index children and their controls. The recent report from the Ontario study (Saigal et al., 2000) also demonstrates that the ELBW children in their study performed particularly poorly in arithmetic. The authors report that only a quarter of those children with birthweights <750g and a third of those with birthweights 750-1000g performed in the normal range. It was also noted that problems with arithmetic were less remarkable at the eight year follow up. The authors account for the increase in difficulties at the older age as being a function of more complex conceptual tasks and the change from simple oral number work to written calculations.

In the Liverpool study, while no significant differences were found in reading ages at eight years of age, by 12 years of age significant differences were reported in reading, reading comprehension and spelling. It has become increasingly common to include a measure of reading comprehension in assessment protocols (e.g., Pharoah et al., 1994). The present study included only the Word Reading scale (a graded reading list) but not a measure of reading comprehension. The Word Definitions subscale of the BAS was, however, administered. This requires the child to define a target word in his or her own words and could be seen as tapping into the same ability as reading comprehension.

While the comparison children in this study achieved, on average, higher reading and word definition scores than the index children, overall 60% of the reading scores were in the normal range whereas the ability to define words was poorer - irrespective of case status. Pharoah et al. found no difference in reading comprehension between index and control girls irrespective of birthweight. For boys there was no difference in the <1000g group but differences were found between index and control boys in the two heavier birthweight groupings. Pharoah et al. did not present the results for speed of reading and reading accuracy, but they were reported to follow a similar pattern. The Scottish study found no gender differences for either reading or number. (This issue is discussed in detail below.)

6.8.1 Underachievement in basic literacy and numeracy skills

The issue of underachievement by low birthweight children has been explored in a number of study groups involved in longitudinal research. Marlow et al. (1993) reported that while the majority of their index children had IQs in the “normal” range and attended mainstream school, many failed to perform satisfactorily at school. In the present study underachievement was defined as a difference of not less than 1 standard deviation between cognitive ability and scholastic attainment in children with IQs of 85 or over.

In this study there was no evidence of a higher prevalence of underachievement in the index population (Table 5.12.3.). This was also the case when the index children were investigated by birthweight grouping, thus even amongst those children of <1000g who were not of below average intelligence the prevalence of underachievement was similar to the rate amongst their heavier birthweight counterparts. This is similar to the findings of Saigal et al. (1991) where the index children at eight years of age were reported to be performing significantly less well than the comparison group, both in terms of ability and attainment, yet most were functioning within the normal range on all measures. As noted above, however, the picture changed for the index children in the Ontario cohort by the time they reach 12 years of age. Underachievement was reported to be more apparent especially in arithmetic and, furthermore, while differences in cognitive ability had not been apparent by birthweight at the eight year follow up, by 12 years the children with lower birthweight were performing significantly less well than the heavier birthweight index children.

The findings in the present study and that of Saigal et al. (1991) differ from those of Marlow et al. (1993); Klein et al. (1989), Nickel et al. (1982) and Saigal et al. (2000). It is possible that the difference in the findings is due to the age at which the assessments are undertaken and to differing definitions of underachievement.

The implication to be drawn from the increasing occurrence of problems over time reported in the Liverpool and Ontario studies is that cohorts of VLBW children need to be followed up into and beyond their teenage years. Children who were apparently free from educational problems in their mid primary school years are found to be experiencing considerable problems by the time they are in early secondary education – perhaps as a result of subtle and latent neurological impairment. This does not augur well for the longer term outcomes of these young people and it is important to continue to monitor their progress in order that the best methods of intervening on their behalf in their early lives can be established.

6.8.2 Reading and number difficulties and the provision of learning support

Of the children identified who performed below the 10th percentile for reading, 81% were receiving learning support, whereas the figure was only 38% in the case of performance below the 10th percentile in number. The smaller proportion of children receiving learning support for difficulty in number as opposed to reading may indicate that failure to acquire reading skills is more readily apparent and considered more important, triggering a faster response in terms of the provision of additional learning support.

It is possible that the findings in the present study relating to the provision of learning support may be flawed. The instructions to teachers in their questionnaire did not make it clear that the term “learning support” was intended to mean the involvement of an additional adult, either teacher or classroom auxiliary. It is possible that some teachers may, quite rightly, have considered extra attention from themselves as constituting additional learning support. In any case, this would not have affected the disproportionate amount of learning support directed towards children with reading difficulties as opposed to number difficulties.

The southern Swedish study (Stjernqvist & Svenningsen, 1999) reported that 43% of their extremely premature cohort had IQs in the subnormal range. Of these, more than half had not been identified by either their parents or their teachers as having special educational needs. They were attending mainstream school and were not in receipt of learning support. The authors conclude that some extremely premature children do not have an optimal situation at school.

The authors made the additional observation that most teachers did not know that the pupil was a preterm child. This was principally because parents had failed to advise them that this was the case - as they did not consider that the fact that their child had been born prematurely as an event that might have a long term impact on the child’s cognitive ability or school attainments. The same was true also in the present study. As the long term picture for these children unfolds, it appears that not only do they fail to catch up but they may indeed fall further behind. There is an argument, therefore, for routinely advising teachers of the birthweight/gestational age status of the children in their class. This, of course, has to be weighed up against the dangers of labelling and self fulfilling prophecies which may lead to a lowering of expectations.

6.9 Neuromotor functioning

6.9.1 Movement Assessment Battery for Children (Movement ABC)

The index children performed more poorly on the motor tasks of the Movement Assessment Battery for Children (Movement ABC), many of which form a part of everyday life for children. These finding support those of Pharoah et al. (1994) and Powls et al. (1995) – two studies where the numbers of index children are comparable. Powls et al. reported, additionally, that girls performed less well than boys, the Scottish study found no such gender differences in motor functioning.

The study by Pharoah et al. investigated motor functioning by birthweight groupings and found that index children <1000g performed less well than those in the 1000-1499g group. When the motor skills of the index children in the present study were investigated by birthweight groupings it was also found that the lower birthweight group was at greater disadvantage than the heavier birthweight group.

6.9.2 Quick Neurological Screening Test (QNST)

The use of the QNST (Mutti et al., 1978) is less well known but draws on the experience of neurologists and psychiatrists with an interest in learning disabilities (Kinsbourne & Warrington, 1962; Bax & MacKeith, 1963; Rutter, Graham & Yule, 1970; Denckla, 1974; Wolff, Gunnoe & Cohen, 1985). As the QNST and the Movement ABC are both assessing neurological competence it is perhaps not surprising that there was 70% concordance between the two tests in the assignment of neuromotor status as normal or impaired – taking index and comparison groups together.

The QNST did, however, appear to be identifying a deficit over and above the purely neuromotor aspects of the Movement ABC. Correcting for motor impairment (using ANCOVA), the QNST was still significantly associated with school attainment. Correcting for performance on QNST, however, motor impairment was no longer significantly associated with reading or number skills. This effect is illustrated in Table 5.12.3 comparing mean scores in Word Reading and Number Skills for four possible outcomes combining the results of the Movement ABC test and the QNST. This demonstrates that, conditional on QNST performance, children with or without motor impairment do not, on average, differ with respect to school attainment.

6.9.3 Screening tools for use in education

Teachers and others working in education strive to identify children with difficulties as early as they can in order to intervene on their behalf as early as possible. It has been suggested recently, however, that the profession of educational psychology has failed to translate theory and research findings that might be applicable to early identification and intervention into professional practice (Desforges, 2000). Failure to intervene early, especially where literacy skills are involved, can result in school failure across the breadth of the curriculum. This in turn can lead to lack of confidence and, in the worst scenario, disinterest, disillusionment and disaffection - sometimes manifested as overt misbehaviour. It is generally accepted that it is easier to support young people with educational needs from the earliest stages to enable them to acquire functional skills and to help them appreciate that much of the school curriculum falls within their capabilities rather than to support young people who have already experienced failure, who lack confidence in their abilities and are, therefore, disinclined to apply themselves to school related work.

As a result of methodological flaws in the Scottish Low Birthweight Study, in particular the lack of a control group at the four year follow up, it has not been possible to identify an assessment tool that can be administered at the pre school stage that is predictive of poor educational outcome later on. This is unfortunate as it is this that would be of most value to teachers, that is, to have "at risk" children identified even before they even reach formal primary education. The Liverpool Maternity Hospital study, although not always employing the same assessment materials at each follow up, has had the advantage of a control group throughout the various phases of the study. As a result, the study team has been able to sidestep the difficulty encountered in the Scottish Low Birthweight Study of the lack of representativeness of published norms to their cohort. Marlow et al. (1993) were able to report that motor testing at six years was the best predictor of school problems at eight years. A score of five or more on the test of motor functioning correctly identified 15 of 16 (94%) of children with significant school problems. Botting (1997) has been able to show that IQ testing at six has the best predictive value for mathematics and reading comprehension at 12 years, although she acknowledges that this would be an inefficient way of selecting children for additional learning support.

Although the present study cannot categorically support the finding of Marlow et al. it is certainly the case at eight years of age that neuromotor competence, especially neurological functioning, is associated with educational attainment. Most studies do not support the idea of "catch up" over time and even the Liverpool Maternity Hospital study which reported some catch up between four and eight years of age finds none thereafter. Intuitively the notion of neuromotor functioning being predictive of later cognitive and educational outcome is appealing.

What the Scottish Low Birthweight study is able to show is that the QNST is a useful screening tool for identifying children at high risk of learning disabilities once they are established in primary education. The QNST is not an instrument that has been designed for use by teachers although it is conceivable that specialist teachers could be trained in its use. It is also unlikely that psychological services would have the human resources to routinely screen all primary school children of eight to nine years of age. It may be possible for doctors and nurses working for the school health service to incorporate the QNST into their routine assessments. In Scotland all children are screened at primary one and primary seven and periodically in between. It may prove possible for school doctors and nurses to incorporate the QNST into a screening at around the primary three stage. This will have allowed enough time to elapse to ensure that children are of an appropriate age for such an assessment but not so late that they will already have started to experience failure in school. Following assessment with the QNST it could be recommended that all children with "abnormal" scores be provided with learning support and those with "suspicious" scores be rigorously monitored.

The identification of children with learning difficulties, as opposed to more severe or profound problems, at the primary three stage would represent a considerable advance on the current state of affairs. If a child has not been identified at the pre school stage as having problems then a referral to the psychological service usually does not occur until around the primary three stage – and often it will be much later, sometimes only after the child has moved from primary to secondary education.

6.9.4 Do incontrovertible neuromotor difficulties ever occur in isolation?

A question of interest in this study was whether incontrovertible neuromotor difficulties ever occur in isolation or if they are always accompanied by problems in other domains of development. Children were classified as having incontrovertible neuromotor impairment if they were performing below the 10th percentile on the Movement ABC and gained either "suspicious" or "abnormal" scores on the QNST.

Of the 300 index children in mainstream education in the study 299 were able to complete the Movement ABC, the QNST and the BAS including the tests of reading and number.

Of the 299 children who could be tested on all measures, 27 performed below the 10th percentile on the Movement ABC and had "suspicious" scores on the QNST but were performing in the average range or above in terms of cognitive ability, reading and number. A further three children performed below the 10th percentile on the Movement ABC and had "abnormal" scores on the QNST but were performing in the average or above average ranges in terms of cognitive ability, reading and number.

This is consistent with the finding of the Hammersmith Study (Jongmans et al., 1998) – the only other study in the literature to investigate this issue. Of the 75 children in their study who failed both tests of perceptual motor functioning, 15 performed adequately on all other measures.

While this question is of interest in its own right it is also of interest in terms of the relationship between Piaget's theory of psychological development in childhood and low birthweight research. This issue is developed below.

6.10 Children who were small for gestational age

There are a number of relatively large scale longitudinal studies of very low birthweight and/or very premature infants that are running very nearly in parallel with the Scottish Low Birthweight Study. These include the Merseyside study (e.g. Pharoah et al., 1994; Hutton et al., 1999), the POPs study (e.g. Verloove Vanhorick et al., 1983), the Bavarian Longitudinal study (e.g. Gutbrod et al., 2000) and the

Liverpool Maternity Hospital Study (e.g. Marlow, et al., 1993). Of these, the Merseyside study and the Bavarian study have investigated the issue of being small for gestational age in most detail.

Reporting on the 12 year follow up of the Liverpool Maternity Hospital study, Botting (1997) acknowledges that issues such as being small for gestation age are worthy of investigation and explains why they were not addressed in her study. She reported that there were very few children who were either SGA or who had birthweights <1000g in her cohort - as the occurrence of both SGA and ELBW was rare in the period in which the babies in her study were born. Botting suggested that the lack of numbers in these groups would have made some analyses impossible and could have hidden significant differences in other comparisons.

The issue of small numbers is, indeed, pertinent. Arguably, however, there were sufficiently high numbers of ELBW children and SGA who were very small and/or very premature being born in the early-mid 1980s to allow such investigations to be carried out. Both the Merseyside study and the present study are reporting upon relatively small number of children with regard to sub groups of the index cohort such as infants with birthweight less than 1000g and infants who were small for gestational age. Botting does not provide details of the numbers of children in her cohort who were either SGA or who had birthweights less than 1000g. In the present study there were 45 children in the index cohort who had birthweight less than 1000g. This was a sufficiently large group to demonstrate significantly poorer performance than comparison children in all areas of development and there were 92 children who were SGA in the index cohort. While this represents less than one third of the index cohort it is still a sizeable group and larger than the ELBW group. It was felt, therefore, that the issue of group size should not prevent an examination of this potentially important area of investigation.

In addition to the 92 SGA children in the index group the SGA/AGA status of 491 of 590 comparison children was known. Sixty two of these children were SGA and 429 were AGA. By definition the birthweights of the comparison children were ≥1750g – the original cut off for inclusion in the Scottish Low Birthweight Study (McIlwaine, Mutch, Pritchard, Fletcher, 1989).

6.10.1.1 Investigation into differences in cognitive ability and scholastic attainment in the index group according to SGA/AGA status

It had been predicted that SGA children would perform less well than AGA children on measures of cognitive ability and scholastic attainment. In the present study no significant differences were found on any measure of cognitive functioning or scholastic attainment between the SGA and the AGA index children. Indeed, any small differences that were observed were in the opposite direction to that which had been predicted – with the single exception of the Speed of Information processing sub scale of the BAS.

The absence of differences between the SGA and AGA children in the cognitive and scholastic domains supports the findings of some other studies (e.g. Abel Smith and Knight Jones, 1990; Pharoah et al. 1994a; Spinollo et al., 1997) but not others (e.g. Fishancho et al., 1994; Pryor et al., 1995; Paz et al., 1996).

A closer examination of the index cohort in the present study, however, demonstrates a bias that calls into the question the validity of the investigation into SGA/AGA differences in the index group. The mean gestational age of the SGA index group was 33 weeks whereas the gestational age of the AGA index group was 29 weeks. As the small differences between the SGA and AGA groups were not significant, no definitive statements can be made on the basis of these results. There was, however, a consistent pattern whereby, with the exception of one subscale of the BAS, the SGA children were outperforming the AGA children who, as it turns out, were, on average, of shorter gestation. This consistent pattern of small differences may be offering a clue that it is gestational age rather than being small for gestational age that is more important as far as longer term cognitive and scholastic outcomes are concerned in this VLBW population.

The investigation into the effects of gestation and birthweight on VLBW SGA children in the Bavarian longitudinal study adopted the methodology of Sung et al. (1993), whereby the index VLBW SGA group was compared with two groups of VLBW AGA children – one matched by gestational age and the other by birthweight. The two studies did not reach the same conclusion as far as growth measures were concerned but, with regard to cognitive development, they were largely in accord. The sample size in the Sung et al. study was relatively small and while the authors tentatively suggest that short gestation has a greater detrimental effect on cognitive development than intrauterine growth retardation the differences reported in their study were not significant. The results from the Bavarian study, however, demonstrated that at 56 months VLBW SGA infants were gaining higher IQ scores, on average, than children in the AGA group matched by birthweight. Thus, the authors of the Bavarian study support the notion that short gestation may be a more important factor than intrauterine growth retardation as far as cognitive development is concerned.

The studies of both Sung et al. and Gutbrod et al. (2000) reported that their AGA comparison groups matched by birthweight had the highest rates of neonatal complications. Gutbrod et al. noted that many studies reporting upon differences between SGA and AGA children fail to report upon, and control for, sociodemographic factors or neonatal complications. The authors reported that in their study the sociodemographic characteristics of the index and comparison groups were very similar and, therefore, differences between the groups on measures of cognitive ability could not be accounted for by such factors. Neonatal complications, on the other hand were more common amongst the comparison group matched according to birthweight. The authors reported that differences in cognitive ability at 56 months were no longer significant after controlling for neonatal complications. The conclusion drawn by the authors was that neonatal complications are more closely associated with early gestation and, therefore, the effect on cognitive development of being SGA is less than that of complications during pregnancy or, especially, during the neonatal period.

6.10.1.2 Investigation into differences in cognitive ability and scholastic attainment in the comparison group according to SGA/AGA status

The investigation into SGA/AGA differences also involved those comparison children for whom SGA/AGA status was known. Again it was predicted that SGA children would gain lower scores, on average, on measures of cognitive functioning and scholastic attainment than the AGA children. As far as general IQ was concerned the difference between mean scores was significant with SGA children gaining lower scores on average than the AGA children. There was also a significantly greater proportion of SGA children performing between 1 SD and 2 SD below the mean. The difference of 4 to 5 IQ points between the SGA and AGA comparison children is rather less than the 5 to 10 points difference in mean IQ scores suggested in one study of term SGA and AGA children (Breart & Poisson, 1988). On the other hand the difference on scores of cognitive ability found in this study was greater than that reported in a study from the late 1990s which suggested that there is no association between SGA and cognitive ability in the longer term (Hack, 1998).

All of the remaining differences between the SGA and AGA comparison children on measures of cognitive functioning were not significant – although they were all, with the exception of Speed of Information Processing, in the predicted direction. As reported in the results chapter, all of these analyses were undertaken using ANOVA and the Tukey HSD post hoc test. Employing either the t-test statistic or a less stringent post hoc test of significance of difference between mean scores would have elicited significant results for both verbal IQ and visual IQ. The Tukey HSD post hoc test is, however, the appropriate one to use given the unequal numbers of children in the groups. Furthermore, it does not represent good statistical methodology to select tests with the aim of simply producing statistically significant results. There should be a rationale for adopting a particular statistical method and this should be applied consistently within a given area of investigation.

With regard to measures of scholastic attainment, the SGA comparison children gained, on average, significantly lower Word Reading and Number Skills scores than the AGA comparison children.

A recent investigation has explored the differential effects of SGA and AGA on cognitive ability in five year old children who were full term at birth (Sommerfelt et al., 2000). The authors reported that the SGA children gained lower IQ scores than their AGA counterparts. Sociodemographic characteristics of the groups were reported and controlled for. As with the Bavarian study, sociodemographic factors did not confound the results.

Sommerfelt et al. went on to consider parental factors such as child rearing style and maternal non verbal problem solving abilities. The authors reported that parental factors accounted for considerably more of the variance in both verbal and non verbal IQ than did SGA/AGA status. The conclusion reached was that there is only a weak association between intrauterine growth retardation and children's cognitive ability whereas there is a considerably stronger association between parental factors and children's cognitive ability. In the present study data were not collected on parental factors such as those reported in the Sommerfelt et al. study. With regard to sociodemographic characteristics, however, as was the case in the Bavarian study and the study of Sommerfelt et al., the SGA and AGA comparison groups in the present study were very similar. Therefore, sociodemographic characteristics probably did not contribute to the differences observed between SGA and AGA comparison children in terms of general IQ, reading and number.

6.10.2 SGA/AGA differences in neuromotor functioning

In the present study motor competence and neurological status were investigated in relation to SGA/AGA status.

6.10.2.1 Investigation into differences in motor competence and neurological functioning in the index group according to SGA/AGA status

For the index children there was no difference in terms of motor competence (Movement ABC test) between the SGA and AGA children. The overall Movement ABC score was similar for both groups. On only one of the individual items was there a significant difference - the performance of the index AGA children in terms of moving pegs on a pegboard with the preferred hand was poorer than that of the index SGA children.

Neurological status was assessed using the QNST. There was little difference, based on SGA status, between the proportion of children categorised as normal or suspicious. There was, however, a significantly higher proportion of AGA index children with abnormal scores – although the numbers were very small (one SGA child (1%) and 14 AGA children (7%)). Individual items of the QNST were investigated in relations to SGA/AGA status and these are reported in Appendix 4. None of the differences was significant at the $p<0.05$ level and, given the large number of comparisons being made, the level of significance would, in any case, be more appropriately set at the $p<0.01$ level.

Thus, as was the case with cognitive ability and scholastic attainment, the predictions were not upheld. Once again, those small differences that did exist were, in general, in the opposite direction to that which was predicted. This finding agrees with that of the Hammersmith group (Jongmans et al., 1997). The authors reported no differences between SGA and AGA children on any of the measures of neurological functioning or perceptual motor competence they administered. The Mersey study (Hutton et al., 1999) found gestational age to be positively associated with poor motor competence but SGA to be negatively associated with motor competence. This differed from their findings in relation to cognitive ability where birthweight, gestational age and SGA were all positively associated with poor cognitive ability. In summary, the findings of Hutton et al. suggest that being born too early is detrimental for all aspects of development and that intrauterine growth retardation is associated particularly with poor cognitive ability.

6.10.2.2 Investigation into differences in motor competence and neurological functioning in the comparison group according to SGA/AGA status

In this study there was no difference in overall Movement ABC scores between the SGA and AGA comparison children. In term of the individual items of the Movement ABC a significantly greater proportion of the SGA comparison children had scores below the 10th percentile for hopping (both with the preferred and the non preferred leg). None of the other differences was significant although they were all in the predicted direction with the exception of two handed catch and moving pegs on a pegboard with the preferred hand.

With regard to performance on the QNST a larger proportion of the AGA comparison children gained normal scores (79% as compared with 69%) the difference, however, was not significant. A larger proportion of the SGA comparison children had suspicious scores (31% as compared with 21%) again, however, the difference was not significant. Once again individual items of the QNST were investigated in relation to SGA/AGA status and no significant differences were found (Appendix 4).

In broad terms the findings with regard to motor competence and neurological functioning in relation to SGA/AGA status reflects the findings of the investigation into cognitive ability and scholastic attainment. In both cases there are no significant differences between SGA index children and AGA index children. There is, however, a consistent pattern, both in the neuromotor and cognitive domains, for SGA children to perform marginally more satisfactorily than AGA children.

With regard to the comparison children, there was a tendency for more of the SGA children to perform below the 10th percentile on the Movement ABC and for more of the SGA children to be classified as "suspicious" on the QNST although the differences were not significant. A tendency for AGA comparison children to perform more satisfactorily than the SGA children was also apparent in the cognitive/scholastic domain and, at least for general IQ, reading and number, the differences were significant.

6.10.3 How are differences in outcome of SGA children born at early and later gestation to be explained?

Infants may be born small for gestational age because of some inherent abnormality of the fetus such as chromosomal abnormality or some other form of congenital abnormality. SGA may also be the result of maternal disease such as pre eclampsia or placental insufficiency (Kramer, 1987; Thomson, 1983). It is possible that the effects of early and late growth retardation may differ because the growth retarded infant that is born in late gestation or, indeed, at full term is likely to have experienced the adverse intrauterine environment for longer than the growth retarded infant that is born at a younger gestational age. Furthermore, the same adverse intrauterine circumstances could result in different effects depending on the stage of organ development at the time of exposure.

An alternative view is that a more intense exposure to an adverse environment may result in growth retardation and the triggering of labour whereas a less intense exposure may lead to only growth retardation. Taking the example of maternal pre eclampsia, mild pre eclampsia might lead only to fetal growth retardation whereas more severe pre eclampsia might result in fetal growth retardation and premature labour. Although perhaps counterintuitive, it is conceivable that a more intense exposure to an adverse intrauterine environment might lead to a better outcome for the infant. This also implies that if intrauterine growth retardation can be successfully identified during pregnancy, there is a case for delivering such infants early. In the present study, of the children whose mothers were admitted to hospital because of "poor growth", 76% were SGA at birth. Of the infants found to be SGA at birth, however, only 19% were identified as growing poorly during pregnancy.

If it is indeed the case that growth retarded infants born at early gestation fare better in the longer term than those born at later gestation and if it continues to be the case that only a modest percentage of growth retarded infants are identified as such during pregnancy, then this offers a clear direction for the development of practice for those health professionals involved in the care of these infants and the ante natal care of their mothers. That is, while doctors and nurses have become skilled at enabling ever smaller and more premature babies to survive they need to develop and apply techniques that allow for the identification of fetuses that are not growing well in utero. Labour should then be induced as early as the health professionals have confidence in the infant's prospects for survival. The assumption is that, once free of the adverse intrauterine environment, there is a more optimistic outlook for the infant's growth and development. However, reaction from the medical profession might be mixed, as very fine clinical judgements are being demanded. There are clearly both ethical and legal implications associated with the early delivery of infants who are not growing well in utero.

6.11 Gender Differences

A strand of investigation in this thesis related to gender differences in outcomes in the VLBW cohort. It is well established that male VLBW children have a smaller chance of survival than female VLBW children. It is less well established, however, that VLBW males experiences higher rates of problems than female VLBW children. To explore this question the female and male index children were compared on all measures of cognitive ability, scholastic attainment and neuromotor functioning employed in this study.

6.11.1 Gender differences in measures of cognitive ability

In the present study both the index children and the comparison children were compared by gender on measures of IQ – including cognitive sub skills.

Index males scored, on average, just one IQ point higher than index females (93.7 and 92.7 respectively). A slightly higher percentage of index females had IQ scores more than 2 SD below the mean. A slightly higher proportion of index females also had IQ scores between 1 SD and 2 SD below the mean. None of these differences was, however, significant.

As far as scores falling in the above average range was concerned the numbers of children were very small for the index group and while there were slightly more female than male children in this range the difference was not significant.

There was almost no difference between mean IQ scores for comparison female and male children and, furthermore the distributions of IQ for female and male comparison children were very similar.

6.11.1.1 Gender differences in measures of cognitive subskills

The seven subscales of the BAS were investigated for gender differences for both the index and comparison groups. No statistically significant gender differences were found on any of these scales for either the index or comparison children. As would be expected from the foregoing, no gender differences were found between mean scores on composite verbal IQ or visual IQ for either the index or comparison groups.

6.11.1.1.1 Comparison of findings on gender differences in cognitive ability between this and other studies

There are relatively few studies that have considered the possibility that vulnerability to impairment, of any description, might differ for girls and boys. Those studies that have considered this issue in relation to cognitive ability have often reported that girls outperform boys (e.g. Jongmans et al., 1998; Verloove Vanhorick et al., 1994; Elliman et al., 1991). The present study, however, found no such gender differences on measures of cognitive ability for either the index or comparison group.

One way of accounting for the differences between the findings in the present study and those of other studies concerns the age of the children at the time of assessment. In the present study the children were eight to nine years of age, whereas other studies have reported on their samples at younger ages (e.g. six years of age in the Jongmans et al. study and five years of age in the Verloove Vanhorick et al. study). Gender differences in maturation during infancy and childhood are well known (e.g. Archer, 1981). Many of these differences, however, level off throughout the childhood years and it may be that by eight to nine years of age gender differences, at least on the cognitive measures employed in this study, are no longer apparent. Verloove Vanhorick et al. have reported an increase in the gender differential in the prevalence of problems in all domains between two and five years of age. Nevertheless, at five years of age the children can still be regarded as being in early childhood. The children in the New Zealand national VLBW cohort (Horwood et al., 1998) were seven to eight years of age at the most recent follow up. The authors reported VLBW males appear to be at no greater risk than VLBW females in terms of overall levels of functioning at this age. In terms of cognitive ability, educational progress and behaviour the chances of poor outcome, relative to the general population, were reported to be the same for boys and girls.

Should the argument that gender differences level off throughout the childhood years be correct, then those studies that have followed cohorts of VLBW and very premature children into their secondary education should find little, if anything, in the way of gender differences. Of the two longitudinal studies that have reported upon their cohorts in their teenage years, the Liverpool study reports upon gender differences in behaviour and psychiatric conditions but not in relation to cognitive ability (Botting, 1997). The Ontario study (Saigal et al., 2000) does not report in any great detail on gender differences in relation to cognitive ability at the teenage years but does include gender as one of a number of variables in a stepwise multiple regression analysis to predict psychometric scores at adolescence. Gender was found to be the weakest predictor of cognitive ability of all the variables included in their model.

6.11.1.2 Gender differences in measures of scholastic attainment

The mean scores for reading and number for index females and males were very similar. A slightly greater proportion of index males than females were performing below the 10th percentile on both reading and number, although the differences were not significant.

Other studies of VLBW children and very premature children have reported gender differences on measure of scholastic attainment (e.g. Jongmans et al., 1998; Pharoah et al., 1994a). Jongmans et al. found that index females gained higher scores than index males while Pharaoh et al. found that, in most of their birthweight groupings, index boys gained higher scores than index girls. Jongmans et al, misreport the findings of the initial report from the present study (Hall et al., 1995) suggesting the results of both studies are in accord. This is not so, the present study found no gender differences in the index cohort.

The picture was slightly different for the comparison children. While there was no significant difference between mean reading scores of female and male comparison children a significantly greater proportion of the male children scored below the 10th percentile.

In the case of number skills, the difference between mean scores for female and male comparison children was significant with females gaining, on average, higher scores than the males. Furthermore, a significantly greater proportion of male children were found to be performing below the 10th percentile.

This reflects the current findings in education that the performance of girls has overtaken that of boys at all levels – despite the apparent absence of differences in cognitive ability (e.g. Powney, 1996).

The same does not seem to apply for the index group. Although not significant, the direction of the small differences observed in the index group is not consistent. The mean word reading scores and mean number skills scores are both marginally higher for boys, whereas a slightly higher proportion of male children were found to be performing below the 10th percentile.

The absence of a gender difference in the index group may be real or it could possibly be accounted for by overcompensation by the parent(s). The parents of children who were VLBW or very premature will be aware of their vulnerability in many areas of development. The school progress of a child is an area where parents can actively become involved with the prospect of making a positive contribution. The effectiveness of parental involvement in children's learning at home, especially in reading, is well documented (e.g. Topping & Wolfendale, 1985). It is plausible that the parents of VLBW children become more thoroughly involved in their children's learning at home than do the parents of children who were not VLBW. This is unlikely to be a complete explanation, however, as recent work has indicated that VLBW children experience longer term emotional and behavioural difficulties that may be associated with abnormal attachment in the early years (Botting, 1987). This would suggest that, at least for some children, overcompensation by parents would not be anticipated.

While not specifically related to the issue of gender differences, the issue of mother-child interaction has been explored in an early intervention study which included a long term follow up phase (Achenbach et al., 1993). The study was designed to investigate the efficacy of nurses' intervention with mothers in the neonatal care unit. The nurses were endeavouring to help mothers adapt to their fragile newborn VLBW babies. There were three groups involved:

i. an experimental VLBW group in which mothers were receiving input from the nurses;
ii. a control VLBW group with no additional input from nurses;
iii. a control group of heavier birthweight infants.

The authors reported that, on measures of cognitive ability, scholastic attainment and behaviour, the experimental VLBW group were outperforming their VLBW peers and were not significantly different to their heavier birthweight peers. It was also reported that that the positive effects of this early intervention were beginning to become apparent by three years of age and significantly so by nine years of age.

The conclusion drawn by the authors was that the relatively inexpensive intervention of improving mother-infant transactions is worthy of consideration – given the finding of positive outcomes in middle childhood in their study.

One of the strengths of the Achenbach et al. study is that it continued for nine years following the intervention. There are no other early intervention studies in the literature that report such a long-term follow-up.

6.11.2 Gender differences in measures of neuromotor competence

The performance of both the index and comparison children on the Movement ABC and QNST was compared in relation to gender.

6.11.2.1 Motor competence

In terms of the overall scores for the index children, 60 (39%) females scored below the 10th percentile (using concurrent norms derived from the comparison group) in comparison to 48 (33%) males. This difference was not significant.

The Mersey Study (Pharoah, et al., 1994a) found, in general, that a greater proportion of index boys, in all three of their birthweight groupings, had poorer motor functioning than index girls. They do not, however, report if these differences were significant. The Hammersmith Study (Jongmans et al., 1998) found that significantly more boys than girls failed one, or both, tests of perceptual motor functioning.

While no conclusive comparison can be made between the findings of this study and those of the Mersey study, it is clear that the findings of this study are not consistent with those of the Hammersmith study. Indeed, where individual items of the Movement ABC are concerned, index girls were found to demonstrate significantly poorer performance on both measures of ball skills (two handed catch and throwing the beanbag) than the index boys.

The pattern of motor performance of comparison female and male children was similar to that of the index children. There was no difference in terms of the proportion of females and males performing below the 10th percentile on the Movement ABC. As was the case for the index children, the performance of the comparison girls in terms of ball skills was significantly poorer than that of the boys. Comparison males, however, performed significantly less well on two of the items in the "balance" cluster (one board balance – non preferred leg and hopping – preferred leg).

6.11.2.2 Neurological functioning

Where some accord exists between the findings of this study and that of the Hammersmith study is in terms of the results of the QNST. A higher proportion of index males recorded "suspicious" scores and "abnormal" scores on the QNST – although only in the case of the latter was the difference statistically significant. The numbers of children gaining abnormal scores was, however, quite small – three females (2%) and 12 males (8%).

Unexpectedly, a significantly higher proportion of comparison males than comparison females gained "suspicious" scores on the QNST - 55 females (18%) and 81 males (28%). It is possible that this is a spurious result – on the other hand it may help explain the relatively poor scholastic progress of boys in comparison to girls. The QNST is a test that purports to identify children with a neurological basis for their learning difficulties. The discussion regarding the school attainments of the comparison children, above, demonstrates the relatively poorly developed reading and number skills of the comparison males. This finding may, therefore, be additional evidence that the QNST is, indeed, a useful screening tool for identifying children at risk of school failure. Clearly there is scope for further research in this area – and a role for educational psychologists in this research.

6.12 Evidence of a gradient of risk with decreasing birthweight

Several studies have postulated an inverse relationship between birthweight and risk of poor outcome with the smallest infants having the highest risk of poor outcome in the longer term and heavier birthweight infants having the lowest risk (e.g. Horwood et al., 1998; McCormick, Workman-Daniels, Brooks-Gunn, 1996; Pharoah, et al., 1994a; Klebanov, Brooks-Gunn, McCormick, 1994a; Breslau, DelDotto, Brown, Kumar, Ezhuthachan, Hufnagle, Peterson, 1994).

The New Zealand study (Horwood et al., 1998) found clear differences on all measures of cognitive, educational and behavioural outcomes between the control group and the index group as a whole. The differences between index children who were <1000g and those who were 1000-1499g were not significant. The authors reported a tendency for poorer outcome in the <1000g group but they added that this was not invariably the case and that rates of problems between the two index groups were generally very similar.

The present study provided an opportunity to investigate this issue in a total Scottish population of VLBW survivors.

6.12.1 Comparison of scores of cognitive ability by birthweight groupings

The mean general IQ score for the <1000g group was 90.4 (SD 11.2), for the 1000-1499g group the mean score was 93.7 (SD 13.6) and for the comparison group (all 590 children) it was 101.3 (SD 12.4). (The results are reported in full in Chapter 5, Section 10.) There was no significant gradient effect for general IQ.

An analysis of the composite verbal and visual IQ scores (ANOVA) elicited a pattern of small, non significant differences for verbal IQ and larger, significant difference for visual IQ. The difference between the mean composite verbal IQ scores for the <1000g, 1000-1499g and the comparison groups (90.6 (SD 10.9), 91.4 (SD 14.4) and 97.4 (SD 13.5) respectively) was not significant. The difference between the mean composite visual IQ scores for the <1000g, 1000-1499g and comparison groups was, however, significant (89.9 (SD 14.9), 96.8 (SD 17.3) and 106.4 (SD 15.2) respectively).

Horwood et al., using the WISC-R, found that a slightly higher proportion of the <1000g children than the 1000-1499g children gained IQ scores less than 85 (24.0% and 21% respectively). The authors did not report the verbal IQ and performance IQ scores separately.

Taking into consideration the discussion above, relating to the possible association between motor competence and performance on the visual processing scales of the BAS, it should be acknowledged that the significant differences in composite visual IQ scores between the groups may be partly explained by differences in motor competence. (Differences between the groups in terms of motor competence and neurological functioning are discussed below.)

6.12.2 Comparison of scores of scholastic attainment by birthweight groupings

With regard to scholastic attainment the <1000g group gained lower mean word reading scores and mean number skills scores than the 1000-1499g group. Only the difference between the mean number skills scores was significant, however. An overall gradient effect by birthweight was found for number but not for reading.

Horwood et al. found no differences between their birthweight groups in terms of the proportion of children experiencing difficulty in number (37.5% of the <1000g group and 37.0% of the 1000-1499g group). As far as reading was concerned they found that the heavier birthweight group had a higher rate of difficulty (23.9% of the <1000g group and 29.3% of the 1000-1499g groups.

6.12.3 Comparison of scores of motor competence and neurological functioning by birthweight groupings

The proportion of children performing below the 10th percentile on the Movement ABC was 50% of the <1000g children, 34% of the 1000-1499g children and 11% of the comparison group (all 590 children). The difference in the proportions of children performing below the 10th percentile between the <1000g and 1000-1499g groups was not significant. The difference in the proportions of children performing below the 10th percentile between the 1000-1499g and the comparison groups was significant. It was not possible to test for an overall gradient effect using the Chi square for trend statistic because of the small numbers in some groupings.

For all of the individual items of the Movement ABC a higher proportion of the <1000g group than the 1000-1499g group performed below the 10th percentile. None of the differences was, however, significant. The 1000-1499g group, in turn, had a higher proportion of children performing below the 10th percentile on all the individual items of the Movement ABC than was the case for the comparison group. With the single exception of throwing the beanbag, the differences were statistically significant. Again it was not possible to test for an overall gradient effect by birthweight.

With regard to the QNST, a higher proportion of children in the 1000-1499g group than in the <1000g group had "normal" scores whereas a higher proportion of the <1000g group had "suspicious" or "abnormal" scores – although none of the differences were significant. A significantly higher proportion of children in the comparison group than in the 1000-1499g group had normal scores. Furthermore, a significantly higher proportion of children in the 1000-1499g group than in the comparison group had suspicious or abnormal scores.

These results are consistent with those of the Mersey study (Pharoah et al., 1994a). Using the Test of Motor Impairment (the predecessor of the Movement ABC) it was reported that rates of impairment were highest for the <1001g group, next highest for the 1001-1500g group and lowest for the 1501-2000g group. The only exception to this pattern of results was the finding that a higher proportion of females in the 1501 –2000g group than in the <1001g group had definite motor impairment (the numbers were, however, very small – 8 (11%) and 1 (8%) respectively).

Pharoah et al. only reported tests of significance between cases and controls within these birthweight groupings, it is not clear, therefore, if the differences in rates of impairment between birthweight groupings are significant.

The generally small differences between the <1000g and 1000-1499g groups in the present study on all measures of neuromotor functioning and most measures of cognitive ability and scholastic attainment prevents a definitive statement being made about the existence of a gradient of risk with decreasing birthweight. The pattern of rates of problems between the birthweight groupings is suggestive of evidence of a gradient model of the relationship between birthweight and levels of functioning – and for visual IQ and number skills it does exist. The findings of Pharoah et al., 1994a and Horwood et al., 1998 would also seem to support such a gradient model. In the present study, without exception, children in the <1000g group had higher rates of difficulties than children in the 1000-1499g group who, in turn, had higher rates of difficulties than the comparison children. This pattern of results was repeated for all measures of cognitive ability, scholastic attainment and neuromotor functioning.

6.13 Is statistical significance in differences between index and comparison children necessarily clinically relevant?

Does it necessarily follow that, in outcome studies of VLBW infants, a statistically significant difference between the index children and their controls is clinically relevant? In other words, while it can be demonstrated that statistically significant differences exist does this necessarily point to a poorer outcome for these children in practical terms? Many studies report a several point difference in IQ or DQ between the index and control groups. More often than not, however, the mean scores of both groups fall within the normal range. Many such studies are dealing with relatively large numbers of children. As a result, relatively small differences between the index and comparison groups, in terms of mean scores on cognitive functioning, can be statistically significant. Is it possible to conclude, however, that these statistically significant differences are clinically relevant? It might be concluded that when differences of 1 SD or more are being reported authors would be justified in arguing that this represents a clinically relevant discrepancy. On the other hand it can be argued that standard deviations are only arbitrary cut offs.

Some studies have found larger differences, exceeding 1 SD, between group mean scores. Saigal et al., 2000, for example, report differences of 13 to 18 points on psychometric measures in the index teenagers compared with their term controls. The authors argue that such differences are both statistically significant and clinically relevant.

It may well be an oversimplification, however, to suggest that unless the differences between mean scores on measures of cognitive functioning exceeds 1 SD the difference is not clinically relevant. The Liverpool Maternity Hospital study, for example, has consistently reported statistically significant differences between the index and control groups from the early primary school years to the early teenage years. The mean IQ scores of the index group have, however, always been within the normal range. When scholastic attainment is investigated, however, the picture is different. Reading scores at the two primary school age follow ups differed little between the index and comparison groups but by the early teenage years the index children were performing more poorly than their heavier birthweight controls.

Thus, changes are occurring with maturation. If it had been assumed at the time of the eight year follow up (Marlow et al., 1993) that reading skills were developing satisfactorily, this would have failed to capture the deterioration that seems to be occurring with the passage of time (Botting et al., 1998). This highlights the importance of long term follow up of these children, as small, albeit statistically significant, differences in early childhood may appear to be of questionable relevance, but these differences can become greater with maturation – taking on greater importance.

6.14 Recent developments in neonatology and the implications for longitudinal research of very low birthweight and very premature infants

The first chapter of this thesis included a detailed account of recent advances in care of infants born close to the limits of viability. This issue is included in this thesis as it impinges on all those involved in the longitudinal research of low birthweight, premature and other vulnerable infants. In essence, studies such as the Scottish Low Birthweight Study are reporting upon cohorts of children born in the early to mid 1980s and who received the neonatal care available at that time – but neonatal care has developed in the intervening years.

The review of recent advances in neonatology makes it clear that survival rates of infants born ever closer to the limits of viability are increasing. What has not been demonstrated, but is nevertheless a possibility, is that the quality of life for these new survivors is also improving. In other words, the differences reported in this study between the index children and their comparisons across all areas investigated might not have been the same had the study been set up, say, a decade later.

This, it turns out, is a particularly difficult question to answer. There are two main reasons underlying this difficulty. Firstly, the literature on the longer term outcome of low birthweight and premature infants born in the 1990s continues to be characterised by a high degree of discrepancy in reported findings. Secondly, there will be greater numbers of children born at very early gestation and of extremely low birthweight in cohorts of children born in the 1990s. The performance of these children, born close to the limits of viability, are likely to lower mean scores on measures of cognitive functioning, school attainment and neuromotor competence. Extremely low birthweight cohorts from the 1980s will have comprised fewer children of such extreme prematurity and birthweight. As a result, outcomes may appear to be no better, or even poorer, for cohorts of infants born in the 1990s, but to compare 1990s cohorts with 1980s cohorts is not to compare like with like. It would be unsafe, therefore, to assume that secular changes in rates of impairment are due to changes in neonatal care practices.

To elaborate on the first issue, a recent review of the world literature has investigated the survival rates, rates of major sequelae and rates of neurodevelopmental impairment in ELBW and extremely premature infants born in the 1990s (Hack & Fanaroff, 1999). Their survey of the world literature revealed that, at 23 weeks gestation, survival rates were anywhere between 2% and 35%. At 24 weeks gestation the range was 17% to 58% and, at 25 weeks gestation, the reported rates were 35% to 85%. Clearly there are wide variations in the reported ranges of survival. The authors account for these wide variations in terms of the criteria employed to assess gestational age and differences in population descriptors, the initiation and withdrawal of treatment and duration of survival considered. Interestingly they do not mention medical expertise as a factor.

The authors report that rates of major neonatal morbidity increase with decreasing gestational age and birthweight but, again, there are wide variations in the reported ranges of rates of impairment.

Overall, notwithstanding the wide variation in the reported ranges of survival across the world, there is little doubt that the chance of survival of extremely low birthweight and extremely premature infants has improved since the 1980s. This can be attributed, most of all, to the use of surfactant therapy and an increase in the use of assisted ventilation in the delivery room. As far as rates of impairment are concerned, however, the picture is much less clear. Hack and Fanaroff found little change in the reported rates of neurodevelopmental disability (e.g. subnormal cognitive function, cerebral palsy and sensory impairment) between 1990s cohorts and earlier cohorts. As mentioned above, however, the distributions of gestational age and birthweight will be skewed towards the lower tail in more recent cohorts. Thus, even apparently small changes in rates of neurodevelopmental impairment could, therefore, be construed as considerably lower rates of impairment in more recent cohorts. That is, these cohorts will include a greater proportion of those infants born close to the limits of viability - who were present in earlier cohort in lower numbers.

The majority of studies reporting upon the longer term outcomes of VLBW infants were set up before the use of surfactant had become well established. Those studies that have investigated surfactant therapy and longer term prognosis have yet to demonstrate any relationship with neurodevelopmental outcome (e.g. Dunn et al., 1998; Survanta Multidose Study Group, 1994; Ferrara et al., 1994). The same is true also for antenatal corticosteroid use which has not been shown to improve neurodevelopmental outcome (e.g. Collaborative Group on Antenatal Steroid Therapy, 1984).

There is no doubt that much has been learnt from long term follow up studies of VLBW infants that were established in the 1980s, not least those that have reported on their cohorts into their teenage years (e.g. Botting et al., 1998; Saigal et al., 2000). It is the case that rates of survival of VLBW children have improved throughout the duration of these studies. However, if new studies had been set up to replace existing studies each time a new advance in neonatal care was implemented then the literature on long term follow up would be sparse.

There is a further argument in favour of continuing established longitudinal studies. Some such studies, including the Scottish Low Birthweight Study, have set up hypotheses relating to the early childhood origins of diseases in adulthood. In the present study, for example, detailed assessments of blood pressure and heart rate were made, with a view to tracking these measures through to adulthood. While there is only minimal interest in the results of such assessments in childhood, there is considerable interest in how such measures develop as the individuals reach adulthood. Unless such studies are allowed to continue in the longer term, research questions such as these cannot be answered and a wealth of potentially valuable data will be abandoned.

6.15 Strengths and limitations of the Scottish Low Birthweight Study

6.15.1 Key strengths of the study

6.15.1.1 Follow up rate

One of the major strengths of this study was the success in the follow up rate that was achieved. Of those children who were eligible to be included in the eight year follow up 96% were traced and assessed.

6.15.1.2 Nature of the cohort

Another key strength of the study was that it comprised a total national population. The cohort of children was geographically defined on the basis that the mother was resident in Scotland at the time of birth. The cohort is not biased, therefore, in terms of differences in hospital admissions policies or differences in polices relating to the provision or withdrawal of treatment.

6.15.1.3 The matching process

In addition to age and gender, school placement was used to match comparison children to index children. The comparison children were selected on the basis that they were being taught in the same class, by the same teacher, as the index children. Not only did this mean that the children were matched on a range of school based factors, it also created a comparison group very similar to the index group on a variety of important social and environmental variables.

6.15.1.4 Assessors were blind to the case status of the children

The author of this thesis and his two research assistants were blind to the birthweight status of the children. This is not the case in most other studies. Botting, 1997, for example, was not blind to the birthweight status of the children and she accepts that, although most of her assessments were objective or behavioural in nature, subtle differences in scoring or coding may still have occurred.

This study had the advantage that the children were assessed in school and headteachers and school staff had been forewarned not to divulge the birthweight status of the children to the assessor. In studies employing a design whereby families and children are visited at home, most families will divulge the child's birthweight status – often inadvertently – even if asked not to.

6.15.2 Key limitations of the study

6.15.2.1 Lack of comparison group in previous phases of the study

The lack of a comparison group at earlier phases of the Scottish Low Birthweight Study seriously impedes any investigation into changes across time and into perinatal or early childhood factors that may be predictive of longer term outcome. The issue of problems in the consistency of diagnosis across time has been well documented.

6.15.2.1.1 Problems of consistency in diagnosis

The problem of consistency in the diagnosis of cognitive, motor and neurological functioning has been demonstrated in a report on children enrolled in the National Heart, Lung and Blood Institute collaborative study (Aylward et al, 1987). Profiles of diagnostic assessment from 40 weeks to 36 months were evaluated in 270 children. The longitudinal stability of diagnoses was greatest for motor functioning and poorest for cognitive functioning. The source of the inconsistency is not clear, possibilities might include problems with psychometric reliability and poor methodology.

The authors reported that there was a one-in-four chance that an infant diagnosed as normal in terms of cognitive functioning at either 40 weeks or nine months would worsen by 36 months. As far as specific diagnoses were concerned, infants diagnosed as suspect or at risk generally improved over time or, at worst, their status became ambiguous. Sociodemographic factors were reported to be more likely to affect diagnoses of cognitive functioning than motor or neurological functioning.

Some studies (e.g. Michelsson et al., 1984) report significant correlations between test results presented at different ages. They use this observation to argue that children at risk of school failure can be identified early and intervention programmes put in place – either before starting school or at the time of starting school. There is a problem, however, in drawing such a conclusion as it is not clear that it is the same children who are failing at the different stages – they are only demonstrating that the proportions of children failing are the same at two different points in time.

Botting, 1997, in her discussion of the limitations in her study, referred to the importance of using the same assessment instruments throughout successive phases of longitudinal follow up. This was not the case in her study, therefore, although she had a matched control group at successive phases of her study, she had difficulty in reaching any firm conclusions about changes in cognitive ability, educational attainment or psychological problems over time. In the present study the same problem occurred but for the opposite reason. In the last two phases of the Scottish Low Birthweight Study the BAS has been used as the measure of cognitive ability and the Movement ABC (previously the Test of Motor Impairment) as the measure of motor competence. It is, however, the absence of a matched control group prior to the eight year follow up that prevents firm conclusions about changes over time being reached. This issue will be discussed in greater detail in sections 6.16 and 6.17 below.

6.15.2.2 Change in the criteria for cohort membership

Children who had birthweights between 1500g and 1749g were lost to the Scottish Low Birthweight cohort at this phase of the study.

While a number of more recent studies have started to focus on infants born ever closer to the limits of viability (e.g. Whitfield, Grunau, Holsti, 1997), there are strong reasons why the focus of low birthweight research should not shift relentlessly towards those infants born close to the limits of viability.

Whitfield et al. argue that it is infants born at the very limits of viability (<800g in their study) that are most at risk of longer term sequelae. While there is no question that such children are at risk of longer term morbidities, the argument of these authors misses an important point. Research indicates that high proportions of children in the 1000g to 1499g and the 1500g to 2499g birthweight groups experience a range of difficulties at school, at home and within the community. Moreover, the difficulties that these children in the heavier birthweight groupings experience often remain hidden until the teenage years (e.g. Botting et al., 1998). To eliminate these heavier birthweight groupings from follow up investigation is to do the children a disservice. If follow up of outcome is terminated in the early childhood years it might be concluded, wrongly, that these children are free from longer term sequelae.

Whitfield et al. regard their focus on the tiniest of survivors as a strength in their study. In the present study, the lowering of the birthweight cut off from <1750g at the four year follow up to <1500g at the eight year follow up is regarded as a weakness. (This lowering of the birthweight criterion was imposed for financial reasons.) The strand of investigation in this thesis into the differential outcomes of SGA and AGA children was largely inconclusive. Had the birthweight criterion remained at less than 1750g there would have been a greater number of SGA children and the gestational age bias may have been less pronounced. This, in turn, might have enabled more conclusive findings to have been reached.

To continue to follow up a cohort of LBW or VLBW children does not preclude an investigation of the outcomes of ELBW children. In the present study one strand of investigation was to separate the index cohort into children with birthweights less than 1000g and those with birthweights between 1000g and 1499g. This is not a unique methodology, the Mersey study (Pharoah, et al., 1994a) and the New Zealand study (Horwood et al., 1998, for example, have taken this approach.

6.15.2.3 Potentially important areas of development not investigated

A major failing in this study at the eight year follow up was the absence of any investigation of language development. This developmental domain had been investigated at the four year follow up (Scottish Low Birthweight Study Group, 1992b) but, principally for reasons of limiting the size of the test protocol, it was not pursued at the eight year follow up. However, language development has proven to be a worthwhile area of research in other studies of VLBW and very premature children (e.g. Wolke & Meyer, 1999).

The present study also failed to include a measure of reading comprehension. This has been valuable addition to the test protocols in other studies (e.g. Pharoah et a. 1994a; Botting et al., 1998). The reading skills of the index children in this study were found to be, on average, an area of relative strength. It was argued earlier that the Word Definitions scale of the BAS is tapping into the same skills. While this is probably true, it is only a second best as it cannot assess a young person's ability to use contextual clues or to draw inferences. The important point is that it is of no benefit to have good decoding skills and/or an extensive sight word vocabulary if this is not accompanied by an ability to extract the semantic value of the text that is being read.

6.16 Changes in the level of cognitive functioning over time

The Scottish Low Birthweight Study does not permit a categorical statement to be made about changes in levels of cognitive functioning over time. This is principally for the reason outlined in detail above. The distribution of IQ reported at four years of age was based on published test norms – as no comparison group was employed. It has been demonstrated that the published test norms for the BAS are not entirely representative of Scottish children of eight to nine years of age.

The mean IQ score for all children <1500g at four years was 92.1 (SD 15.3). This compares with a mean IQ of 93.2 (SD 13.3) at eight to nine years of age. At four years of age the mean IQ of those children <1000g at birth was 91.9 (SD 15.3), this compares with a mean IQ of 90.4 (11.1) at eight to nine years of age. The mean IQ at four years of those children who were 1000-1499g at birth was 92.3 (SD 15.2) and at eight to nine years of age the mean IQ was 93.7 (SD 13.6). Thus, mean IQ score differences between four and eight years of age are modest.

Using published test norms, the distribution of IQ at four years of age demonstrated that 5.3% of children <1500g at birth had IQ scores less than 70, that is, the proportion with serious cognitive impairment. By eight years of age the proportion of children with IQ scores less that 70 was 3.4%.

Considering those children who were <1000g at birth, 6.7% had IQs less than 70 at four years of age and by eight years of age none of this group had IQs less than 70.

At first sight this appears to be indicating that the index group, especially those of extremely low birthweight, are "catching up" in terms of cognitive functioning. When concurrent norms are used, however, the picture of the proportion of children with serious cognitive impairment is different. For the entire index group 11% had IQ scores more than 2 SD below the mean for the comparison group and 14 % of the <1000g group had IQ scores in this range. Again, for the aforementioned reasons, it is impossible to state whether or not this represents a deterioration in cognitive functioning – in terms of the proportion of children with serious cognitive impairment – over time. It does, however, reemphasise the importance of employing control groups in longitudinal studies of this type and, where possible, generating concurrent norms from the control group.

6.16.1 Is the recent literature suggestive of a deterioration in cognitive functioning with maturation for VLBW/very premature children?

While many studies have reported marked deteriorations in scholastic attainment with maturation it has not been demonstrated that this is the case for IQ scores (Saigal et al., 2000; Botting et al., 1998). The most recent report from the Liverpool Maternity Hospital Study group (Botting et al., 1998) has shown that basic literacy skills, which had appeared to be developing satisfactorily at eight years of age, had deteriorated by 12 years of age. It is not clear, however, that this is associated with a deterioration in general cognitive ability. The Liverpool Maternity Hospital Study is not well placed to answer this question as a cognitive ability was not assessed at the eight year follow up. At the six year follow up, however, an eight point difference between index and comparison groups was reported – using the WPPSI as the test of cognitive ability. The mean IQ score on the WISC at 12 years of age for the index group was 89.7 (SD 17.2) and for the comparison group the mean IQ was 97.8 (SD 17.4). Thus, the differences between the two groups changes very little between six and 12 years as far as mean IQ scores are concerned – albeit using to different assessment batteries.

Saigal et al., 2000 reported a deterioration in arithmetic scores between eight and 12 years of age, but not in reading or spelling scores. The WISC-R was used as the measure of cognitive functioning at both eight and 12 years. The mean IQ score for the ELBW cohort at eight years was 90 (SD 19) and at 12 years it was 90 (SD 18). Thus, there was no difference in level of cognitive functioning in the ELBW cohort over this six year period. (Saigal et al. added, however, that some deterioration in IQ scores were observed between eight and 12 years of age for children in the lowest birthweight grouping, that is, children who were <750g at birth.) The results for the matched comparison group demonstrated negligible change over this six year period.

Mean IQ scores at four years of age and at eight years of age both for the whole Scottish VLBW cohort (all <1500g) and by birthweight groupings (<1000g and 1000-1499g) were discussed above. At least as far as mean IQ scores are concerned there appears to be very little deterioration between four and eight years of age. Thus the findings of the present study tend to corroborate the findings of the Liverpool Maternity Hospital Study and the Ontario Study. (Whether or not a greater proportion of the Scottish index children have serious cognitive impairment by eight years of age remains equivocal.)

The Bavarian Study has recently reported upon a large cohort (n=264) of very premature children at six year of age (Wolke & Meyer, 1999). The mean Mental Processing Composite (MPC) scores were reported for the very preterm cohort and also the subset of the cohort that excluded those with major neurological impairment. The Bavarian group has carried out a subsequent follow up study on the very preterm cohort and, although the findings have not yet been published, the initial indications are that there is no deterioration in mean MPC scores.

The general pattern of development for VLBW and very preterm children would, therefore, appear to be characterised by stability in general cognitive ability but with contemporaneous deterioration in other developmental domains – especially scholastic attainment. It may be that this population of children are experiencing a degree of general cognitive fragility – which tends not to deteriorate with maturation – but which results in greater levels of difficulty in other domains as the demands placed upon them, especially by the education system, increase with the passage of time.

6.17 Predictors of later outcome in VLBW children

It is beyond the scope of this thesis to investigate assessment measures at four years that are predictive of outcome at eight year. Similarly perinatal variables are not considered. As far as the four year data are concerned, as discussed above, the Scottish Low Birthweight study is flawed in that the four year follow up did not employ a matched comparison group – instead published age norms were used to evaluate the progress of the VLBW children across a range of developmental areas. Using a matched control group at the eight year follow up has demonstrated that the published norms of tests of motor functioning and, to a lesser extent, cognitive ability, are not representative of the Scottish population of eight to nine year olds. It has been frequently pointed out (e.g. Kaufman, Doppett, 1976; Wolke et al., 1994) that published age norms must be relevant to the particular social and ethnic groups concerned. The standardisation samples for the WISC-R, for example, demonstrate that white children from social class I have, on average, full scale IQ scores of 109.4

whereas for black children from social class V the average full scale IQ score is 81.5. This is a particularly extreme example but it serves to provide a clear illustration of the need to describe the socio economic and cultural composition of study samples and populations.

In the present study there is a problem in relating the eight year data to the four year data in order to discover what measures at four years of age are predictive of later outcome. The age norms used at four and a half years of age, it turns out, were not representative of Scottish schoolchildren. The Movement ABC, for example, part of the eight year assessment protocol, is designed to identify children performing in the lower 15% of the population. A more stringent cut-off point of the 10th percentile was used to classify children as motor impaired in this study. Using published norms, a surprisingly high proportion of the eight year comparison group (28%) were found to fall below the 10th percentile for overall motor performance. Clearly this presents a problem in terms of relating the findings of the four year study to the findings of the eight year study. The strength of studies such as the Liverpool Maternity Unit Study (e.g. Powls, et al., 1996) is that matched comparison groups have been followed up alongside the index group. This enables the problem experienced by the Scottish Low Birthweight Study to be overcome.

With regard to cognitive measures at four years and at eight years, scores on General IQ and Recall of Digits (BAS) were correlated. (Recall of digits is the only subscale of the BAS that is appropriate for both four year olds and eight year olds.) While the correlation coefficients in both cases were high, this hides the fact that children who scored well at four years were not necessarily the same children who scored well at eight years. When such correlations are undertaken scatter plots will often demonstrate outliers. It may be that a productive area for future research would be a detailed study of these outliers. That is, what are the particular characteristics of children who have made marked improvement in, for example, cognitive ability and, similarly, what are the particular characteristics of those children who demonstrate a marked deterioration.

As far as perinatal variables are concerned, only a cursory investigation was carried out on selected variables in relation to selected eight year outcomes. Multiple regression analysis found only that maternal age at the time of birth was significantly associated with general IQ at eight years of age. The literature concerning VLBW studies attempting to identify perinatal risk variables is characterised by discrepant findings. Individual differences with respect to outcome are commonly reported with some infants doing well and others much less so. As the study of the 'new survivors' of neonatal intensive care has progressed, it has become apparent to investigators that outcome is dependent not only on perinatal risk variables but also on the interaction of these variables with environmental factors such as social class (e.g. Eilers, Desai, Wilson, Cunningham, 1986; Gyler, Dudley, Blinkhorn, Barnett, 1993; Mutch, Leyland, McGee, 1993; Weisglas-Kuperus, Baerts, Sauer, 1993; Caputo, Goldstein, Taub, 1981).

6.17.1 The association of socioeconomic variables with outcome

In this phase of the Scottish Low Birthweight Study there is a considerable amount of missing data as far as sociodemographic factors are concerned – especially social class. The missing data resulted from a relatively poor return rate of parental questionnaires. As a result of the extent of the missing data it was decided not undertake rigorous statistical analysis to investigate the relative effects of socioeconomic status and birthweight status on cognitive ability.

Some recent studies have, however, undertaken a thoroughgoing investigation of this issue (e.g. Wolke & Meyer, 1999; Stjernqvist & Svenningsen, 1999). The six year follow up of the Bavarian study (Wolke & Meyer, 1999) reported scores on intellectual functioning (The Mental Processing Composite [MPC] of the Kaufmann ABC) grouped by socioeconomic status. The authors reported a clear effect of social class but with no interaction between social class, group status or gender. There was no overlap of scores between the index children and the comparison children. In other words, even the comparison children from the lowest social class grouping scored higher than the very preterm children from the highest social class grouping. Thus the effect of very preterm birth was greater than the effect of socioeconomic factors.

Other large scale long term follow up studies have reported findings that are broadly in accord with the Bavarian study (e.g. Eilers et al., 1984; Lloyd et al., 1988; McCormick et al., 1989; Saigal et al., 1991; Pharoah et al., 1994a; Levy Shiff et al., 1994; Stjernqvist & Svenningsen, 1999).

The Bavarian group has also undertaken a further level of analysis of this issue which is less common in long term follow up studies. The authors investigated the occurrence of normal cognitive functioning, mild cognitive impairment and severe cognitive impairment in both the index and control groups by socioeconomic status (SES).

The authors reported that the occurrence of mild cognitive impairment in the comparison group was twice the rate for children of low SES as compared with children of middle or high SES. Furthermore, only comparison children of low SES were reported to have serious cognitive impairment.

The SES effects were reported to be rather less evident for the index group. The number of children with mild cognitive impairment was greatest in the middle SES group and the number of children with serious cognitive impairment was greatest in the lowest SES group. However, testing whether SES was predictive of serious cognitive impairment was not significant.

Much research on the survivors of neonatal intensive care suggests that sociodemographic factors have a greater effect on long term cognitive outcomes than biological risk factors as the children mature (e.g. Forfar et al., 1994; Levy Shiff et al., 1994; Hack et al., 1995). The Bavarian Study demonstrates that SES is related to all cognitive scores with children from families of higher SES, irrespective of case status, obtaining higher scores than those from families of middle SES who, in turn, obtained higher scores than those of lower SES. Importantly, however, the effect sizes for the influence of prematurity were much higher than those of SES.

The results of the Bavarian Study also suggest that very premature children are at double jeopardy. That is, the effects of prematurity and SES were found to be independent from each other and, therefore, additive. Thus those children who performed most poorly were those index children of lowest SES but they did not perform disproportionately worse than comparison children of lowest SES. In other words the performance of all children, whether at biological risk or not, is adversely affected by poor socioeconomic conditions.

6.18 Psychological theories and low birthweight research

As this thesis is concerned with the development of VLBW children in the psychological domains of cognitive ability and scholastic attainment – together with motor competence and neurological functioning – it is appropriate to consider the findings in relation to developmental theory. This issue is introduced in chapter 2 above, and an overview of Piaget's theory is provided. The focus is on Piaget's theory as it was the first to provide a comprehensive account of psychological development from birth to adolescence. Moreover, Piaget's theory, more than any other theory of child development, has withstood the test of time. It has provided a paradigm for empirical research in developmental psychology throughout a large part of the 20th century and continues so to do.

A notion that is central to Piaget's theory of cognitive development is that thought develops from action. In Piaget's view there is a "logic of action", in other words, a practical logic of relationships and classes in terms of sensory motor action. For Piaget, infants who are born with many means of interacting with their environment, construct and test hypotheses about their world. He believed that this process, which occurs initially at the sensorimotor level, is a necessary precursor of the representational logic that is characteristic of the concrete operational stage.

It follows, therefore, that a subgroup of VLBW children that is of particular interest is one characterised by incontrovertible motor difficulties. According to Piaget's theory these infants would be regarded as being most at risk of experiencing associated difficulties in psychological domains – as the quality of their interactions with their environment will be less satisfactory than that of their peers who are of adequate neuromotor competence.

As described in detail above, 27 of the index children in this study performed below the 10th percentile on the Movement ABC and had "suspicious" scores on the QNST but were performing in the average range or above in terms of cognitive ability, reading and number. In addition, three of the index children performed below the 10th percentile on the Movement ABC and had "abnormal" scores on the QNST but were performing in the average or above average ranges in terms of cognitive ability, reading and number. Thus, overall, 10% of the index group had incontrovertible motor difficulties but were without associated cognitive or scholastic problems.

This is consistent with the finding of the Hammersmith Study (Jongmans et al., 1998) – the only other study in the literature to investigate this issue. Of the 75 children in their study who failed both tests of perceptual motor functioning, 15 performed adequately on all other measures.

The results of this study, and that of the Hammersmith group, demonstrate that it is not always the case that children with motor difficulties experience associated problems in the cognitive and scholastic domains of psychological development. This runs counter to the outcome that would be predicted from Piaget's theory. It is important, however, to consider the ages of the children at the time of assessment. In the present study the children were between eight and nine years of age and in the Hammersmith study the children were aged between six and a half and seven and a half years of age. A recurring theme in this thesis is that poor functioning, especially in the scholastic domain, tends to become more apparent with the passage of time. It may be, therefore, that those children with incontrovertible problems of motor functioning who appear not to have any associated problems at approximately eight years of age, will go on to demonstrate difficulties later on. In other words, their difficulties remain hidden – at least until eight years of age.

It has been suggested above that, on the basis of Piaget's theory, it is plausible that early stages of conceptual development might be delayed. VLBW children will, almost without exception, have a more impoverished interaction with their environment than their heavier birthweight peers who did not require neonatal intensive care. If this poor quality of interaction with the environment were the sole reason for the delay in conceptual development of VLBW infants then it would be predicted that progress should improve with the passage of time and certainly after two or three years. The weight of evidence, however, suggests that these infants experience longer term difficulties and that the severity of their educational problems increases over time.

6.18.1 Does sensorimotor thinking only influence conceptual development in early childhood?

One explanation is that interference during the sensorimotor stage of development, arising from poorly developed sensory and neuromotor functioning is, of itself, an insufficient explanation.

Bruner suggested that sensorimotor thinking does not end in early childhood. He believed that, throughout life, certain concepts are best represented not as words or images but through action. These Bruner termed 'enactive representations'. There is evidence both from the low birthweight literature (e.g. Powls et al., 1996) and the literature on clumsiness in childhood (e.g. Losse, Henderson, Elliman, Hall, Knight, Jongmans, 1991) that problems with motor functioning persist at least into the teenage years.

While this might account to some extent for longer term difficulties in cognitive ability and scholastic attainment, it seems counterintuitive that more than a small proportion of concepts are represented through action, as opposed to words and images, in late childhood and adulthood. However, scholastic delay is not necessarily a result of conceptual difficulties. It could be that problems of motor functioning impede the development of automatic, well practiced skills in some areas and educational problems seem to have cumulative effects – becoming magnified over time.

6.18.2 Do theories of child development pertain to the population of VLBW children?

A second, alternative, view is that Piaget's theory and, indeed, theories of developmental psychology in general, do not provide an adequate model for the psychological development of this population of children.

In the overview of Piaget's theory in chapter 2 above, it was stated that research on infants that are of low birthweight inevitably means that almost all are also of short gestation. Psychological theories of child development, on the other hand, are inevitably based upon children of appropriate birthweight and full gestation. There is reason to suppose, however, that the brain of a neonate born at early gestation is fundamentally different to that of an infant born at term of appropriate birthweight –

in terms of aspects of its organisation such as synaptic connectivity – and this may continue to be the case beyond the neonatal period. It may be that we are devoid of psychological theories of child development that pertain to the population of children born at short gestation.

6.18.2.1 Fetal brain development at different stages of gestation

It has been suggested that the brain is not fully developed at birth and some processes such as axon retraction continue into postnatal life and such processes are intimately tied up with the development of normal function (Janowsky & Finlay, 1986). These authors argue that normal neuron loss and axon retraction are uniquely developmental events – unlike other neuroanatomical processes such as sprouting and changes in synaptic efficacy. It follows, therefore, that disruption or alteration to these developmental processes is likely to differentially affect infants born at early gestation, term infants and adults.

The capacity of the brain to reorganise following damage will vary according to when in time the disruption occurs. Janowsky and Finlay suggest if the immature patterns of synaptic connections become stabilised then this might result in the sparing of certain capacities that might be lost following adult lesions but may disrupt undamaged capacities.

It is plausible, therefore, that the brain of an infant born at early gestation may be characterised by a pattern of synaptic connectivity that affects developmental processes well beyond the neonatal period. There are many studies reporting upon infants who appear neurologically normal in early life but who go on to experience learning and behavioural difficulties in their school years. Some studies are now reporting on psychiatric sequelae in the teenage years (e.g. Botting, 1997).

It has long been argued that very low birthweight, extreme prematurity and neonatal illness influence development and maturational processes rather than leading to outcomes that can be clearly defined and understood (St. James-Roberts, 1987). It may be that the diametrically opposed findings reported in some studies, for example, the relative sparing or otherwise of short term auditory sequential memory, may be due to the gestational age distributions of the samples

6.18.2.2 Is the process of myelination in VLBW children disrupted?

It has been suggested that the process of myelination is disrupted where there is reduced availability of plasma phospholipid arachidonate (Miller, 1994). This is manufactured from long chain fatty acids, in particular, linoleic acid. Human breast milk contains long chain fatty acids which tend to be lacking in standard infant formulas. Furthermore, substantial improvements in IQ have been demonstrated in premature infants fed with their mother's milk (Lucas, Morley, Cole, Lister, Leeson-Payne, 1992).

Miller noted that plasma phospholipid arachidonate is an important component of myelin and, therefore, lower availability of plasma phospholipid arachidonate would be likely to lower myelin production and, in turn, intelligence. That is, myelin production is associated with brain volume which, in turn, is associated with intelligence.

Miller cites research that indicates that plasma phospholipid arachidonate is important not only for myelination but also for bodily growth and that it is positively correlated with head circumference in the preterm infants at two months and at four months – with the correlation gradually declining up until 12 months.

It is plausible that lower plasma phospholipid arachidonate availability lowers myelin production which, in turn, affects head circumference. There is evidence from the low birthweight literature that VLBW infants with subnormal head circumference in the first year of life have lower IQs and educational attainments later on (e.g. Hack et al., 1991).

Miller notes that the body can manufacture plasma phospholipid arachidonate from the essential long chain fatty acid linoleic acid but it cannot make linoleic acid. It remains equivocal, however, whether or not levels of linoleic acid are reduced in premature infants. There is the possibility, however, that in VLBW and very preterm infants limited availability of plasma phospholipid arachidonate is preferentially utilised for bodily growth at the expense of myelination and, therefore, intelligence.

6.18.2.3 Do theories of child development pertain to the population of VLBW children? – conclusion

Given the likelihood of differences in brain organisation and the possibility of disruption in the process of myelination, the applicability of existing theories of child development to this particular population of children must be called into question. As stated above, theories of psychological development in childhood are based upon children born at full term of appropriate birthweight. Although the population of VLBW children do appear to follow a largely normal developmental pattern, there are strong indications that they do not catch up but go on to experience persistent difficulties in a range of developmental domains. It may be that existing theories will need to be modified to capture the developmental processes of the population of new survivors of neonatal intensive care.

6.19 Conclusion

A continuation of the massive research effort of the last two decades is necessary in order to map out the longer term development of the new survivors of neonatal intensive care. It should also be the aim of this research effort to try to tease out the innumerable medical and psychological variables that are associated with the variable of VLBW. VLBW infants differ from their heavier birthweight counterparts not only in terms of their birth weight but, almost always, on a range of other variables such as perinatal characteristics, appropriateness of size for gestational age and social and cultural environment. As these are confounding variables it remains largely unclear which are responsible for differences in long term outcome between VLBW children and their heavier birthweight peers.

Most studies in the literature report upon the outcomes of their index cohort at a given age at follow up and a minor part of the report is devoted to an investigation of perinatal variables that are associated with the outcomes observed. The publication of many hundreds of such reports has resulted in a vast knowledge base about the longer term outcomes of VLBW and very premature infants (with a reasonably high degree of consistency in the reported findings) but much less in the way of knowledge regarding perinatal risk factors (with considerable disparity in reported findings).

Arguably that part of the research effort that strives to identify those perinatal factors that are truly predictive of later outcomes needs a reorganisation of its approach. One such reorganisation would be the coordination of future research effort whereby VLBW cohorts are subdivided into discrete categories - based upon their heterogeneous collection of early developmental impairments. This, in turn, might allow the dissimilar findings reported in the literature to be clarified. One strand of enquiry in this thesis, namely, the appropriateness of size for gestational age, was an attempt to investigate one element of this heterogeneous collection of early developmental factors – albeit to a greater or lesser extent inconclusive. This type of research effort, however, might lead to a greater degree of consistency in research findings, making it possible to offer appropriate advice and recommendations to the agencies involved in intervention at the neonatal, pre school and school stages.

The 12 year follow up of the Liverpool Maternity Hospital study (Botting, 1997 and Botting, et al., 1998) demonstrates the importance of continuing the follow up of VLBW and very premature children into their secondary school years. At the eight year follow up no differences were found on measures of reading between index and comparison children while, by 12 years of age, significant differences were found to exist in reading accuracy, reading comprehension and speed of reading. This would seem to indicate that underlying problems remain hidden in the early school years but, possibly as a result of the ever increasing demands of school education, school performance deteriorates throughout late primary and early secondary education.

Subtle difficulties experienced by VLBW children at earlier years as demonstrated, for example, by their performance on the QNST in this study, which appear not to be associated with a major problems in their wider progress may, in fact, provide a clue to greater problems, particularly within the context of education, that lie ahead.

“It therefore behooves psychology to continue developing techniques for unravelling the multiple interrelated biological, social, societal and cultural variables determining both optimal and less than optimal outcome in such infants.” (Hoy et al., 1988, p. 67)

Epilogue

There is little doubt that differences do exist between VLBW children and children who are born are born at an appropriate birthweight. The main theme of this thesis was such a comparison and, in all of the areas investigated, the index children, as a group, were distinguishable from their heavier birthweight comparison children at eight to nine years of age.

Not only do VLBW children fail to catch up but, as many longitudinal studies have demonstrated, their difficulties become more pronounced over time – especially in the domain of scholastic development. The effectiveness of intervention programmes is not very encouraging. Some studies have demonstrated short term gains, but where longer term follow up has been carried out, these early gains have rarely been maintained – especially in extremely low birthweight children. The conclusion that has to be drawn is that it is better not to be born at very low birthweight or very prematurely. Assuming that it would be unacceptable to society to establish cut off points for birthweight and gestation whereby neonatal intensive care is withheld, the development that needs to take place is the prevention of children being born at very low birthweight and at early gestation. In Scotland, however, as in the rest of the developed world, there is no sign of any reduction in the incidence of low birthweight or prematurity, indeed the proportion of children born under 1500g continues to increase.

In this study, while the index group appeared to have fewer parents in non manual occupations, the difference in social class distributions was not significant. The literature as a whole, however, points to a well established association between low socioeconomic status and low birthweight which, in turn, suggests that those children who survive will not be raised in an optimal social environment. It follows, therefore, that the most effective way to tackle the issue of low birthweight and prematurity is to address the wider issue of social disadvantage. This, at best, is bound to be a long term goal. In the meantime, it will fall to those involved in the neonatal care of these vulnerable infants and to those who support them and their families beyond the neonatal period in health, education and social work, to continue to improve their methods of intervention to bring about the best possible outcome for these children.

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Appendix 1

Low Birthweight Research – Additional Descriptive Statistics

A.1 Detailed Description of index and comparison groups

A.1.1 Mean birthweights and birthweight distributions

The mean birthweight and distribution of birthweight for the index group (all children <1500g, male and female) is presented in chapter 5. The mean birthweights and distributions of birthweight by gender are presented on the following pages.

A.1.1.1.1 Mean birthweight and birthweight distribution for female index children (all <1500g)

The mean birthweight and distribution of birthweight for index females was as follows:

TABLE A.1.1.1.1
Mean birthweight of female index children (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (female)	151	1205g	650g	1495g	206g

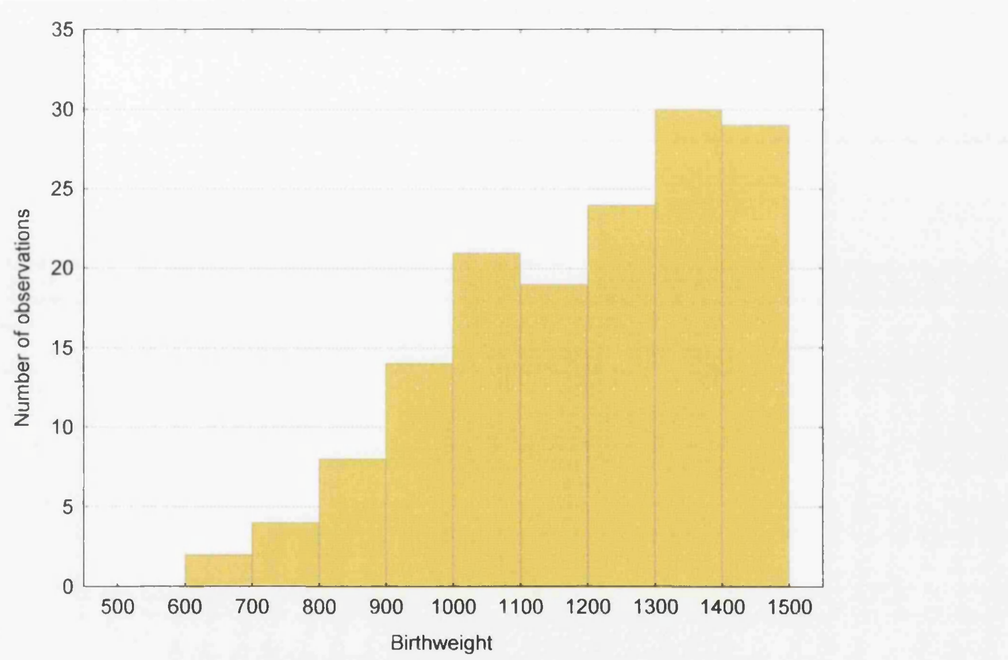

Figure A.1.1.1.1 Birthweight distribution for female index children (all<1500g)

A.1.1.1.2 Mean birthweight and birthweight distribution for male index children (all <1500g)

The mean birthweight and distribution of birthweight for index males was as follows:

TABLE A.1.1.1.2
Mean birthweights of male index children (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (male)	146	1250g	770g	1490g	191g

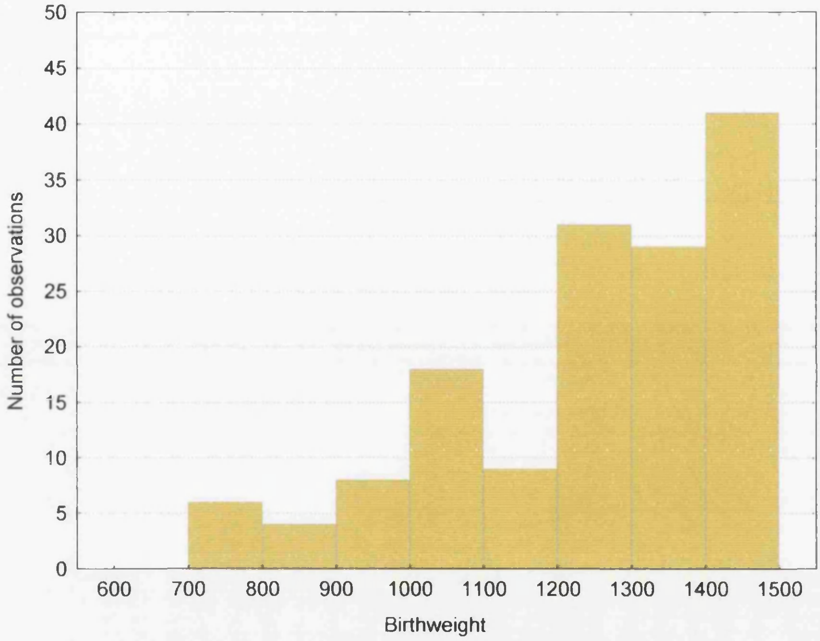

Figure A.1.1.2 Birthweight distribution for male index children (all<1500g)

A.1.1.2 Mean birthweights and birthweight distributions by birthweight groupings

The mean birthweight and birthweight distribution of the ELBW group (all children <1000g, male and female) is presented in chapter 5. Presented below are the mean birthweights and distributions of birthweight by birthweight groupings according to gender.

A.1.1.2.1 Mean birthweight and birthweight distribution for female index children (<1000g)

The mean birthweight and distribution of birthweight for ELBW females (<1000g) was as follows:

TABLE A.1.1.2.1
Mean birthweight of female index children (<1000g)

	N	Mean	Minimum	Maximum	Standard Deviation
ELBW group (female)	26	868g	650g	980g	92

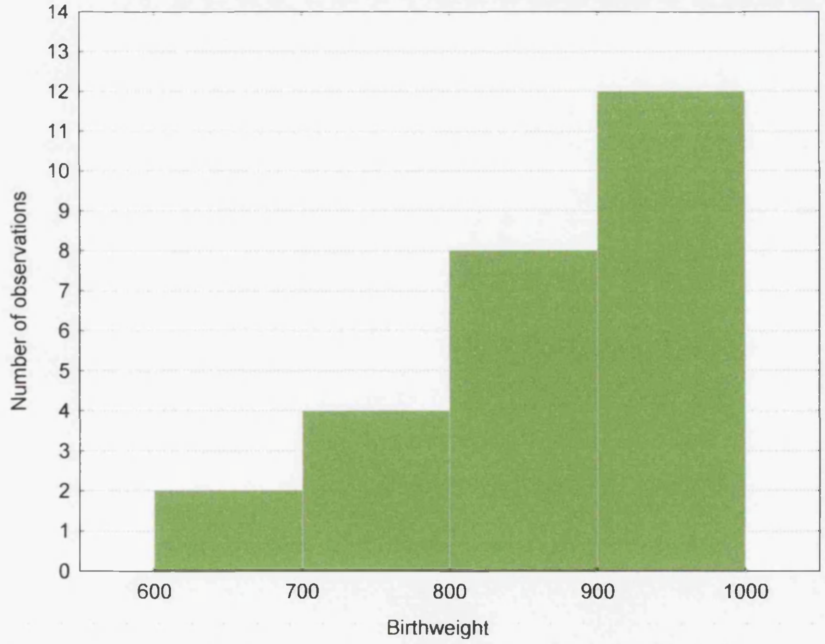

Figure A.1.1.2.1 Birthweight distribution for female index children (<1000g)

A.1.1.2.2 Mean birthweight and birthweight distribution for male index children (<1000g)

The mean birthweight and distribution of birthweight for ELBW males (<1000g) was as follows:

TABLE A.1.1.2.2
Mean birthweights of male index (<1000g) children

	N	Mean	Minimum	Maximum	Standard Deviation
ELBW group (male)	18	872g	770g	992g	77

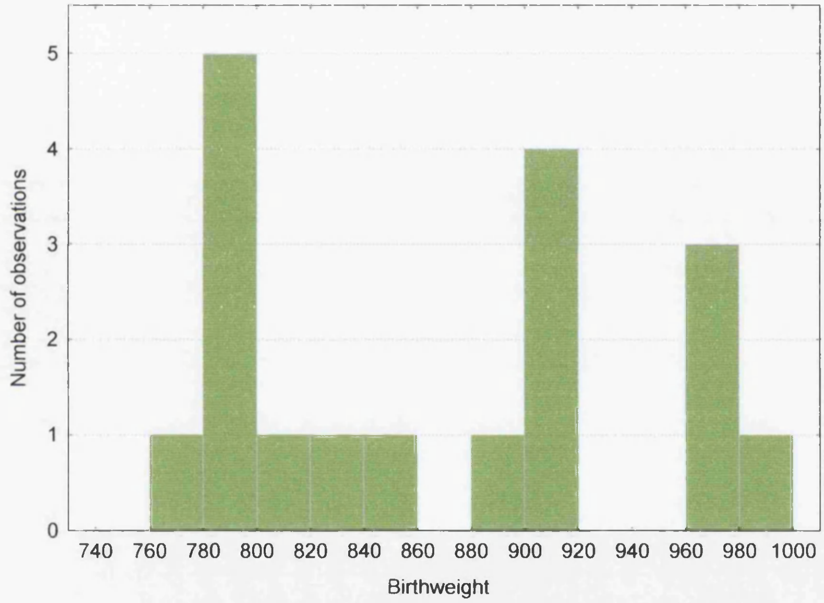

Figure A.1.1.2.2 Birthweight distribution for male index children (<1000g)

A.1.1.3 Mean birthweight and birthweight distribution for female index children (1000-1499g)

The mean birthweight and distribution of birthweight for VLBW females (1000-1499g) was as follows:

TABLE A.1.1.3.1
Mean birthweight of female index children (1000-1499g)

	N	Mean	Minimum	Maximum	Standard Deviation
VLBW group (female)	125	1275g	1000g	1495g	144

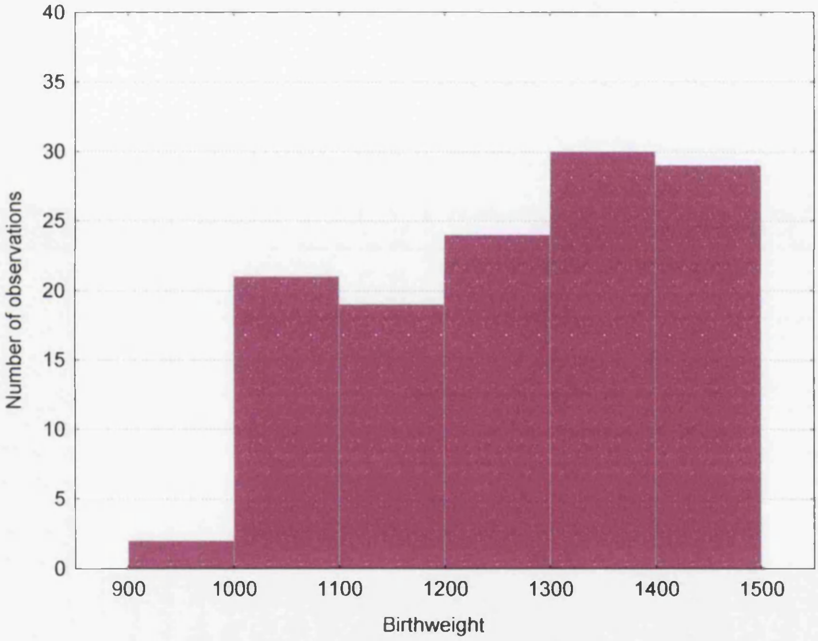

Figure A.1.1.3.1 Birthweight distribution for female index children (1000-1499g)

A.1.1.3.2 Mean birthweight and birthweight distribution for male index children (1000-1499g)

The mean birthweight and distribution of birthweight for VLBW males (1000-1499g) was as follows:

TABLE A.1.1.3.2
Mean birthweights of male index children (1000-1499g)

	N	Mean	Minimum	Maximum	Standard Deviation
VLBW group (male)	128	1303g	1003g	1490g	134

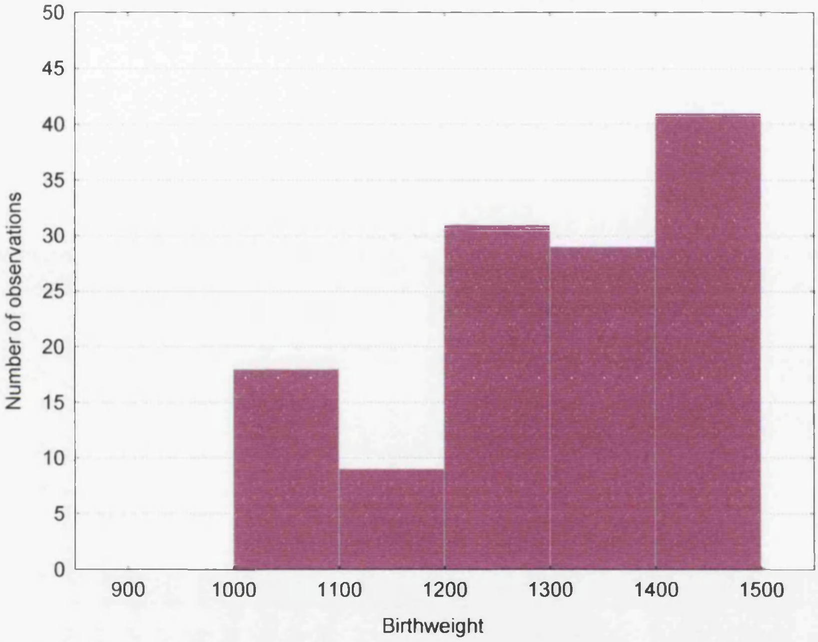

Figure A.1.1.3.2 Birthweight distribution for male index children (1000-1499g)

A.1.2 Mean gestational ages and gestational age distributions

The mean gestational age and distribution of gestational age for the index group (all children <1500g, male and female) is presented in chapter 5. The mean gestational ages and distributions of gestational age by gender are presented below.

A.1.2.1.1 Mean gestational age and gestational age distribution for female index children (all <1500g)

The mean gestational age and distribution of gestational age for index females (all <1500g) was as follows:

TABLE A.1.2.1.1
Mean birthweight of female index children (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (female)	151	30.2 weeks	24.0	39.0	2.6

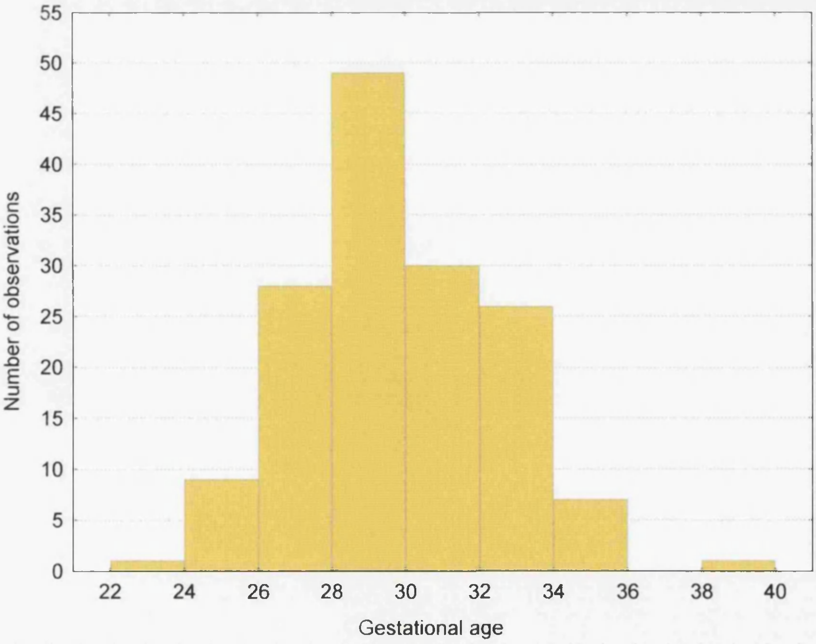

Figure A.1.2.1.1 Gestational age (weeks) distribution for index females (all<1500g)

A.1.2.1.2 Mean gestational age and gestational age distribution for male index children (all <1500g)

The mean gestational age and distribution of gestational age for index males (all <1500g) was as follows:

TABLE A.1.2.1.2
Mean birthweight of male index children (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (male)	146	30.3 weeks	24.0	40.0	3.0

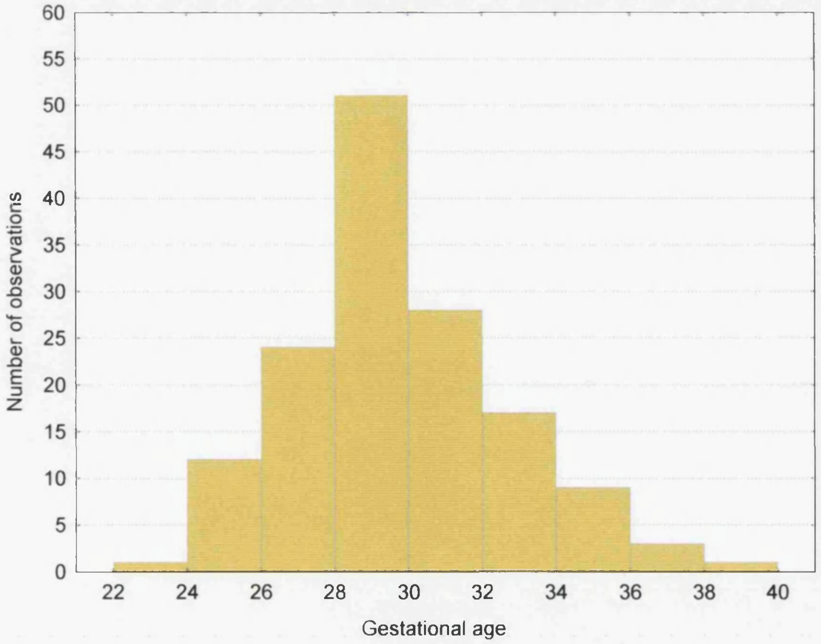

Figure A.1.2.1.2 Gestational age (weeks) distribution for index males (all<1500g)

A.1.2.2.1 Mean gestational age and gestational age distribution for female index children (<1000g)

The mean gestational age and distribution of gestational age for ELBW females (<1000g) was as follows:

TABLE A.1.2.2.1
Mean birthweight of female index children (<1000g)

	N	Mean	Minimum	Maximum	Standard Deviation
ELBW group (female)	26	28 weeks	24	33	2.4

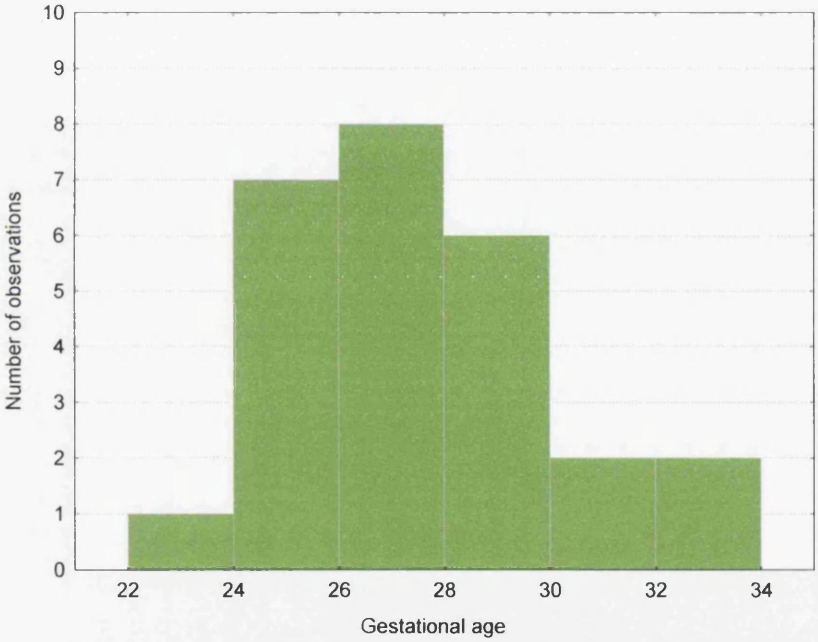

Figure A.1.2.2.1 Gestational age (weeks) distribution for female index children (<1000g)

A.1.2.2.2 Mean gestational age and gestational age distribution for male index children (<1000g)

The mean gestational age and distribution of gestational age for ELBW males (<1000g) was as follows:

TABLE A.1.2.2.2
Mean birthweight of male index children (<1000g)

	N	Mean	Minimum	Maximum	Standard Deviation
ELBW group (male)	18	26 weeks	24	30	1.4

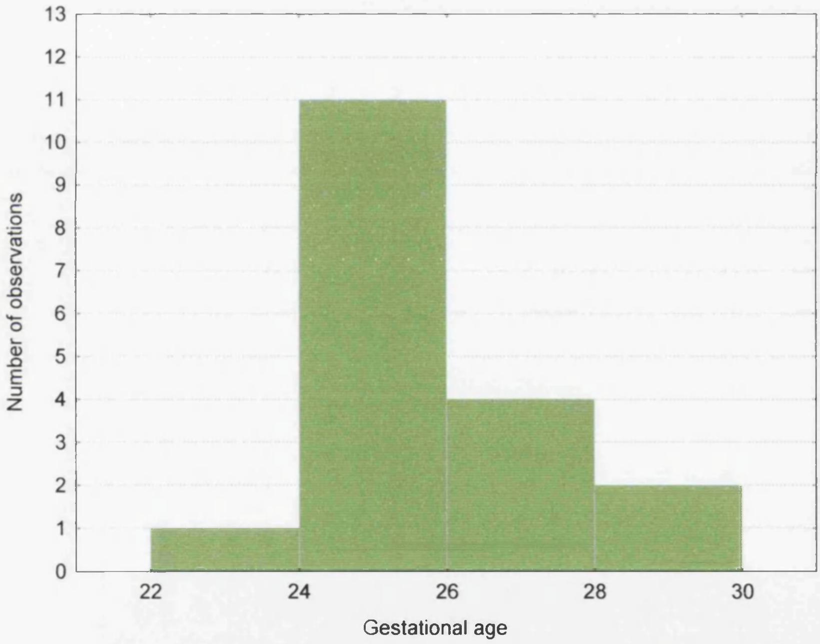

Figure A.1.2.2.2 Gestational age (weeks) distribution for male index children (<1000g)

A.1.2.3.1 Mean gestational age and gestational age distribution for female index children (1000-1499g)

The mean gestational age and distribution of gestational age for VLBW females (1000-1499g) was as follows:

TABLE A.1.2.3.1
Mean birthweight of female index children (1000-1499g)

	N	Mean	Minimum	Maximum	Standard Deviation
VLBW group (female)	125	31 weeks	26	39	2.4

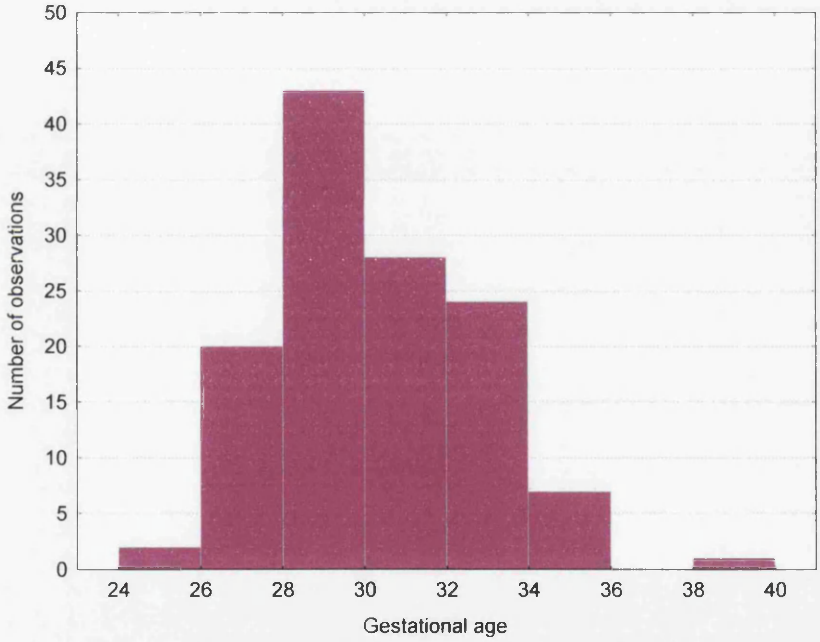

Figure A.1.2.3.1 Gestational age (weeks) distribution for female index children (1000-1499g)

A.1.2.3.2 Mean gestational age and gestational age distribution for male index children (1000-1499g)

The mean gestational age and distribution of gestational age for VLBW males (1000-1499g) was as follows:

TABLE A.1.2.3.2
Mean birthweight of male index children (1000-1499g)

	N	Mean	Minimum	Maximum	Standard Deviation
VLBW group (male)	128	31 weeks	26	40	2.7

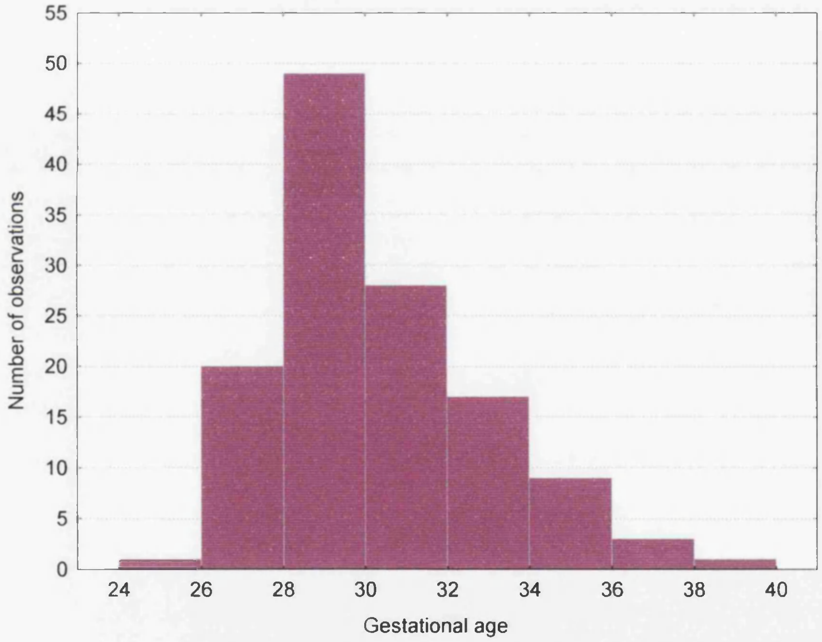

Figure A.1.2.3.2 Gestational age (weeks) distribution for male index children (1000-1499g)

A.1.3 Age distributions

A.1.3.1 Age distribution for index group at time of assessment

The mean age and distribution of age at time of assessment for the index group (all children; female; male) are presented in chapter 5. Mean ages and distributions of age at time of assessment by gender for the index group are presented below.

A.1.3.1.1 Mean age and age distribution for female index children at time of assessment

The mean age and distribution of age at time of assessment for index females was as follows:

TABLE A.1.3.1.1
Mean age of female index children at time of assessment (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (female)	153	8.80	8.10	9.80	0.31

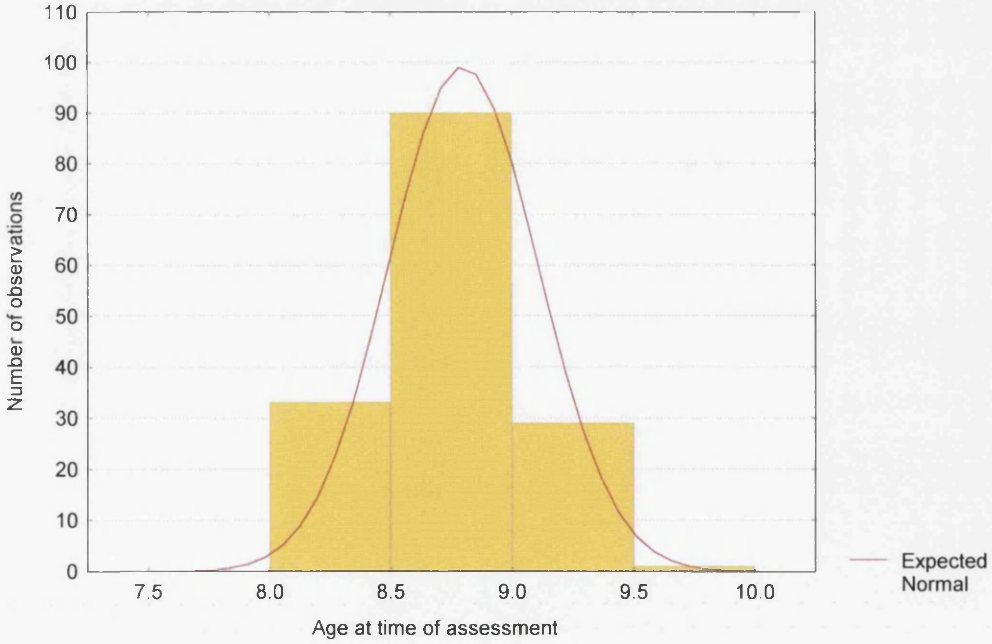

Figure A.1.3.1.1 Age distribution for index females at time of assessment (all<1500g)

A.1.3.1.2 Age distribution for male index children at time of assessment

The mean age and distribution of age at time of assessment for index males was as follows:

TABLE A.1.3.1.2

Mean age of male index children at time of assessment (all <1500g)

	N	Mean	Minimum	Maximum	Standard Deviation
Index group (male)	147	8.83	8.10	9.50	0.33

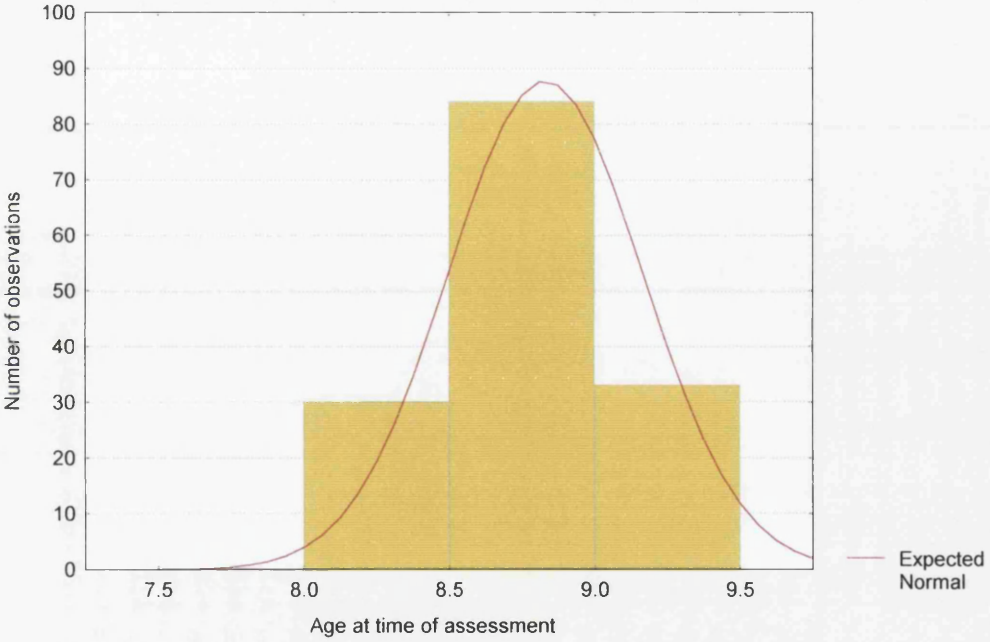

Figure A.1.3.1.2 Age distribution for index males at time of assessment (all<1500g)

A.1.3.2 Age distribution for the comparison group at time of assessment

The mean age and distribution of age at time of assessment for the comparison group (all children; female; male) are presented in chapter 5. The mean ages and distributions of age at time of assessment by gender for the comparison group are presented below.

A.1.3.2.1 Age distribution for female comparison children at time of assessment

The mean age and distribution of age at time of assessment for comparison females was as follows:

TABLE A.1.3.2.1
Mean age of female comparison children at time of assessment

	N	Mean	Minimum	Maximum	Standard Deviation
Comparison group (female)	298	8.75	6.50	9.60	0.36

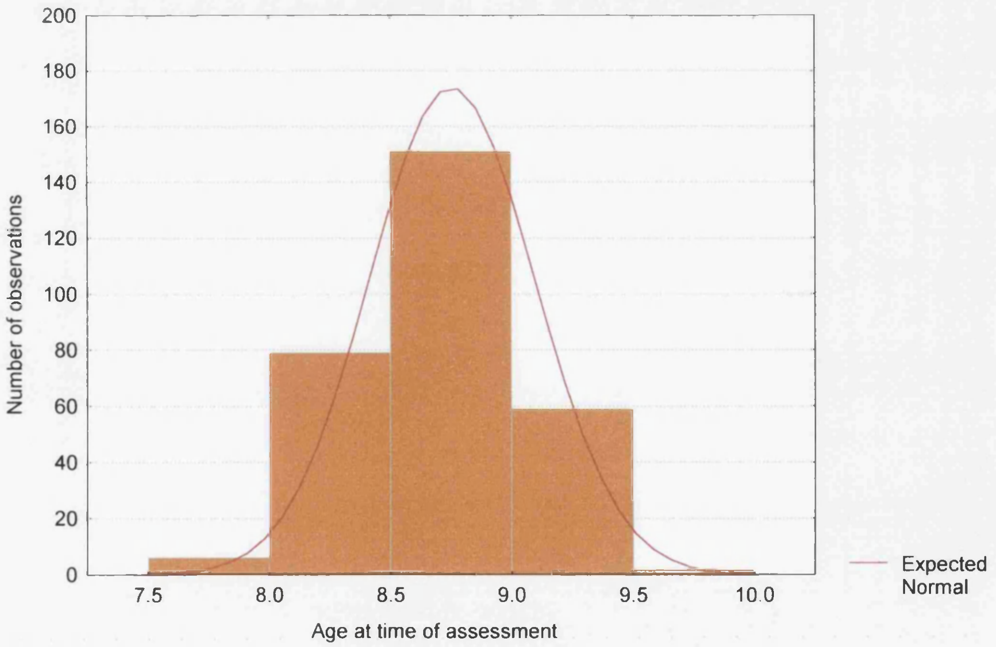

Figure A.1.3.2.1 Age distribution for comparison females at time of assessment

A.1.3.2.2 Age distribution for male comparison children at time of assessment

The mean age and distribution of age at time of assessment for comparison males was as follows:

TABLE A.1.3.2.2
Mean age of male comparison children at time of assessment

	N	Mean	Minimum	Maximum	Standard Deviation
Comparison group (male)	292	8.78	7.00	10.60	0.40

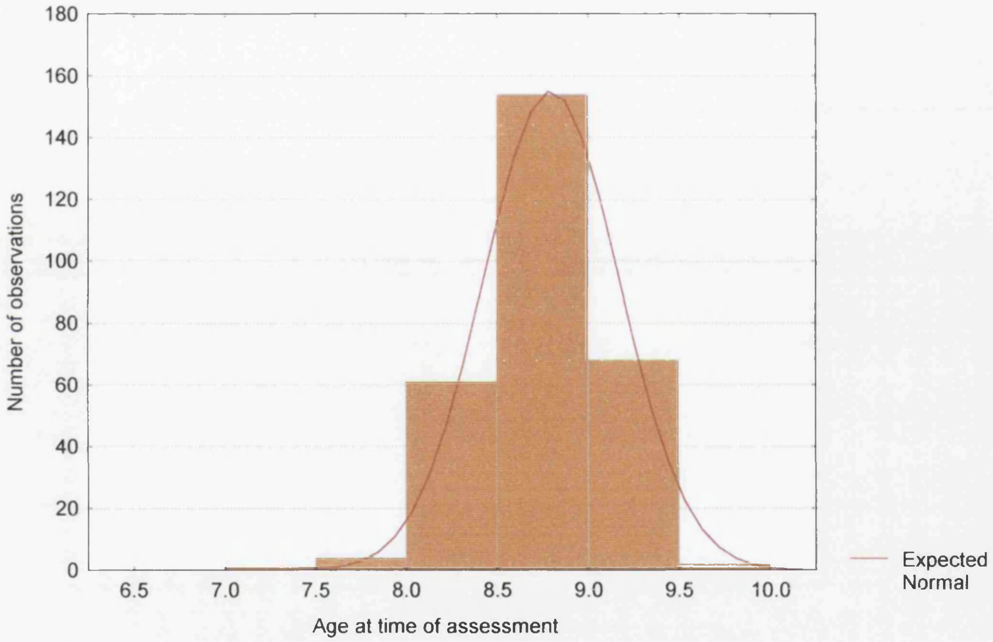

Figure A.1.3.2.2 Age distribution for comparison males at time of assessment

Appendix 2

Low Birthweight Research – Additional Details of Statistical Analyses

A.2.1 Differences in mean composite IQ and sub skills scores (British Ability Scales) between the index (all <1500g) and comparison groups

On the following pages are details of the tests of significance between mean scores on all cognitive assessments.

Table A.2.1.1 is a presentation of the tests of significance of differences in mean scores between the index group (all <1500g) and the comparison group on the British Ability Scales (BAS) composite IQs (general IQ, verbal IQ and visual IQ).

Table A.2.1.2 is a presentation of the tests of significance of differences in mean scores between the index group (all <1500g) and the comparison group on all of the subscales of the BAS.

TABLE A.2.1.1

Differences in mean IQ scores (general; verbal; visual) (British Ability Scales) - index (<1500g) versus comparison children

	VLBW			Comparison								
	N	Mean	SD	N	Mean	SD	t-value	Df	p	Levene F (1, df)	df	p Levene
General IQ	299	93.2	(13.3)	590	101.3	(12.4)	-8.94	887	0.000	1.26	887	0.26
Verbal IQ	299	91.3	(13.9)	590	97.4	(13.5)	-6.41	887	0.000	0.06	887	0.81
Visual IQ	300	95.7	(17.1)	590	106.4	(15.2)	-9.48	888	0.000	7.61	888	0.01

TABLE A.2.1.2

Differences in mean T scores on cognitive scales (British Ability Scales) - index (<1500g) versus comparison children

	VLBW			Comparison								
	N	Mean	SD	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Cognitive Subskill												
Similarities	299	48.4	(9.7)	590	50.9	(9.7)	-3.67	887	0.000	0.03	887	0.86
Recall of Digits	300	48.2	(10.4)	590	49.0	(9.1)	-1.22	888	0.222	9.94	888	0.00
Speed of Information Processing	300	47.3	(10.4)	590	52.2	(10.1)	-6.81	888	0.000	0.15	888	0.70
Word Definitions	299	39.6	(9.6)	590	43.1	(9.4)	-5.22	887	0.000	0.25	887	0.62
Matrices	300	45.9	(9.5)	590	50.0	(8.9)	-6.37	888	0.000	2.27	888	0.13
Recall of Designs	300	50.8	(10.3)	590	55.5	(9.0)	-6.97	888	0.000	7.65	888	0.01
Block Design	300	47.3	(10.9)	590	53.6	(9.8)	-8.63	888	0.000	8.80	888	0.00

A.2.1.1 Box and whisker plots for differences in mean composite IQ scores between the index (all <1500g) and comparison groups

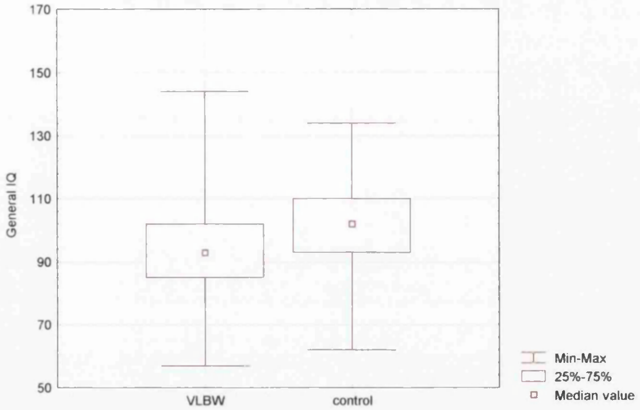

Figure A.2.1.1 *Box and whisker plot for general IQ by case status (all <1500g and controls)*

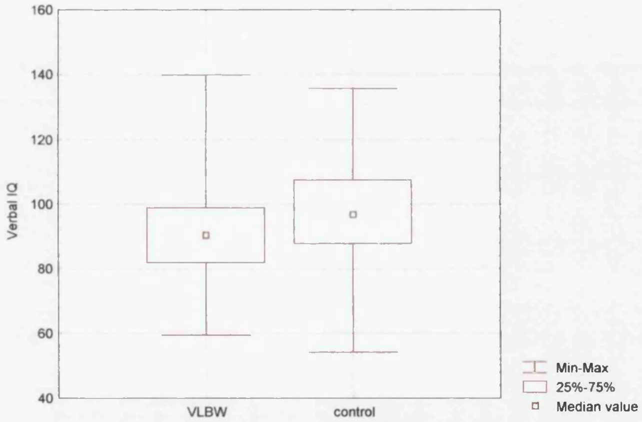

Figure A.2.1.2 *Box and whisker plot for verbal IQ by case status (all <1500g and controls)*

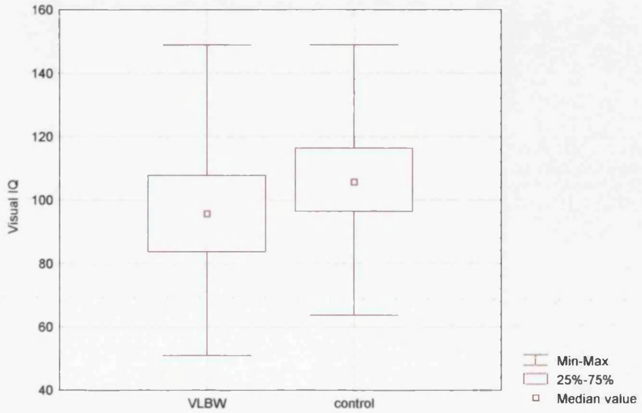

Figure A.2.1.3 *Box and whisker plot for visual IQ by case status (all <1500g and controls)*

A.2.2 Differences in mean composite IQ and sub skills scores (British Ability Scales) between the index and comparison groups by birthweight groupings (<1000g and 1000-1499g)

Tables A.2.2.1 and A2.2.2 are presentations of the tests of significance of differences in mean scores between the index groups (<1000g and 1000-1499g) and the respective comparison groups on the British Ability Scales (BAS) composite IQs (general IQ, verbal IQ and visual IQ).

Tables A.2.2.3 and A.2.2.4 are presentations of the tests of significance of differences in mean scores between the index groups (<1000g and 1000-1499g) and the respective comparison groups on all of the subscales of the BAS.

TABLE A.2.2.1

Differences in mean IQ scores (general; verbal; visual) (British Ability Scales) - index (<1000g) versus comparison children

	<1000g			Comparison A								
	N	Mean	SD	N	Mean	SD	t-value	Df	p	Levene F (1, df)	df	p Levene
General IQ	44	90.4	(11.1)	90	102.5	(12.4)	-5.44	132	<0.0001	0.490	132	<0.49
Verbal IQ	44	90.6	(10.9)	90	98.5	(13.6)	-3.37	132	<0.0001	0.003	132	<0.96
Visual IQ	45	89.9	(14.9)	90	107.8	(14.8)	-6.60	133	<0.001	2.721	133	<0.10

TABLE A.2.2.2

Differences in mean IQ scores (general; verbal; visual) (British Ability Scales) - index (1000-1499g) versus comparison children

	1000-1499g			Comparison B								
	N	Mean	SD	N	Mean	SD	t-value	Df	p	Levene F (1, df)	df	p Levene
General IQ	255	93.7	(13.6)	500	101.1	(12.4)	-7.47	753	<0.0001	1.927	753	<0.17
Verbal IQ	255	91.4	(14.4)	500	97.3	(13.4)	-5.56	753	<0.0001	0.163	753	<0.01
Visual IQ	255	96.8	(17.3)	500	106.2	(15.2)	-7.63	753	<0.0001	7.323	753	<0.69

TABLE A.2.2.3

Differences in mean T scores on cognitive scales (British Ability Scales) - index (<1000g) versus comparison children

	<1000g			Comparison A								
	N	Mean	SD	N	Mean	SD	t-value	Df	p	Levene F (1, df)	df	p Levene
Cognitive Subskill												
Similarities	44	48.3	(9.6)	90	51.9	(10.0)	-1.96	132	0.052	0.06	132	0.80
Recall of Digits	45	50.1	(10.7)	90	49.4	(9.1)	0.41	133	0.681	0.51	133	0.48
Speed of Information Processing	45	45.4	(11.8)	90	52.6	(10.2)	-3.68	133	0.000	1.56	133	0.21
Word Definitions	44	37.6	(9.1)	90	43.3	(9.5)	-3.29	132	0.001	0.36	132	0.55
Matrices	45	43.0	(9.2)	90	50.8	(7.9)	-5.13	133	0.000	2.28	133	0.13
Recall of Designs	45	47.6	(8.9)	90	56.0	(8.8)	-5.18	133	0.000	0.09	133	0.77
Block Design	45	45.2	(9.1)	90	54.1	(9.3)	-5.32	133	0.000	0.32	133	0.57

TABLE A.2.2.4

Differences in mean T scores on cognitive scales (British Ability Scales) - index (1000-1499g) versus comparison children

	1000-1499g			Comparison B								
	N	Mean	SD	N	Mean	SD	t-value	df	p	Levene F (1, df)	df	p Levene
Cognitive Subskill												
Similarities	255	48.4	9.7	500	50.7	9.6	-3.14	753	0.002	0.05	753	0.82
Recall of Digits	255	47.8	10.4	500	48.9	9.1	-1.50	753	0.134	9.29	753	0.00
Speed of Information Processing	255	47.7	10.1	500	52.2	10.1	-5.82	753	0.000	0.02	753	0.89
Word Definitions	255	39.9	9.7	500	43.1	9.4	-4.29	753	0.000	0.10	753	0.75
Matrices	255	46.4	9.4	500	49.9	9.1	-4.88	753	0.000	0.56	753	0.47
Recall of Designs	255	51.4	10.5	500	55.4	9.0	-5.48	753	0.000	8.04	753	0.00
Block Design	255	47.7	11.2	500	53.5	9.9	-7.22	753	0.000	9.98	753	0.00

A.2.2.1 Box and whisker plots for differences in mean composite IQ scores between the index (all <1500g) and comparison groups

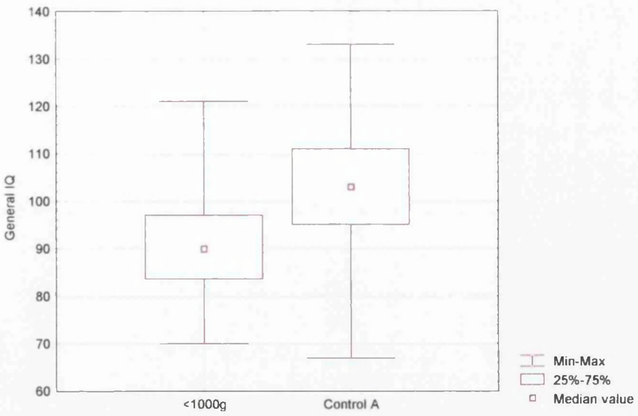

Figure A.2.2.1 *Box and whisker plot for general IQ by case status (<1000g and control A)*

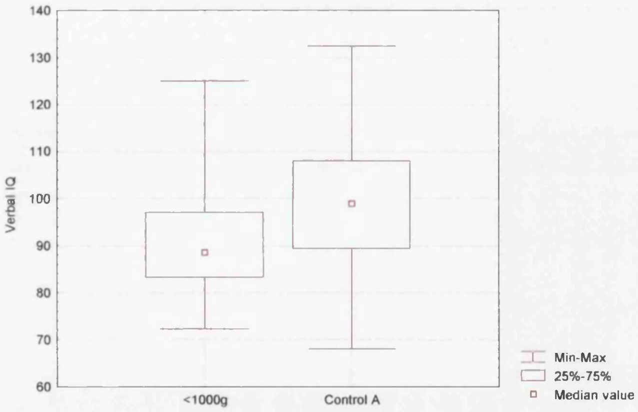

Figure A.2.2.2 *Box and whisker plot for verbal IQ by case status (<1000g and control A)*

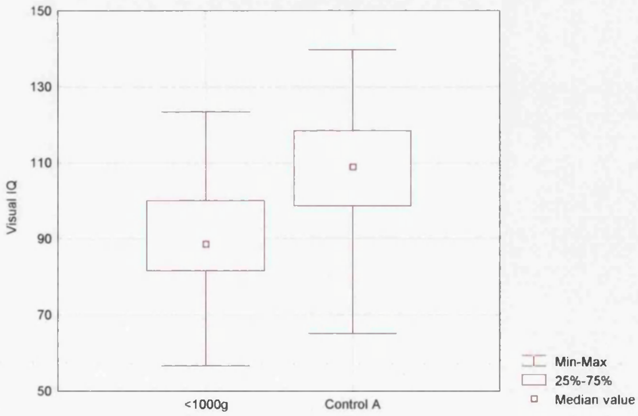

Figure A.2.2.3 *Box and whisker plot for visual IQ by case status (<1000g and control A)*

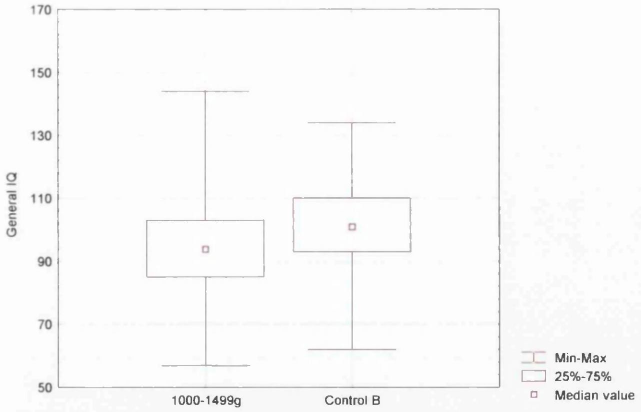

Figure A.2.2.4 *Box and whisker plot for general IQ by case status (1000-1499g and control B)*

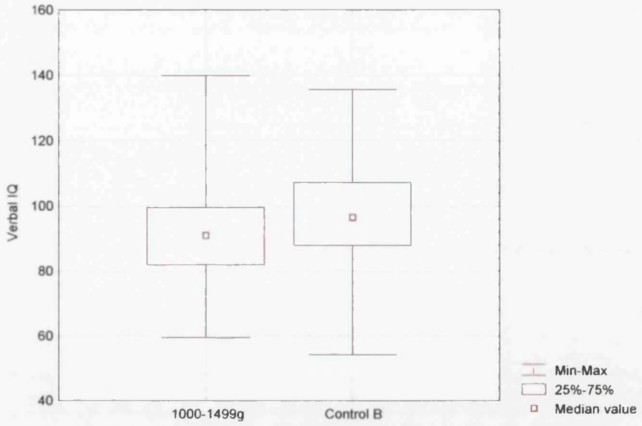

Figure A.2.2.5 *Box and whisker plot for verbal IQ by case status (1000-1499g and control B)*

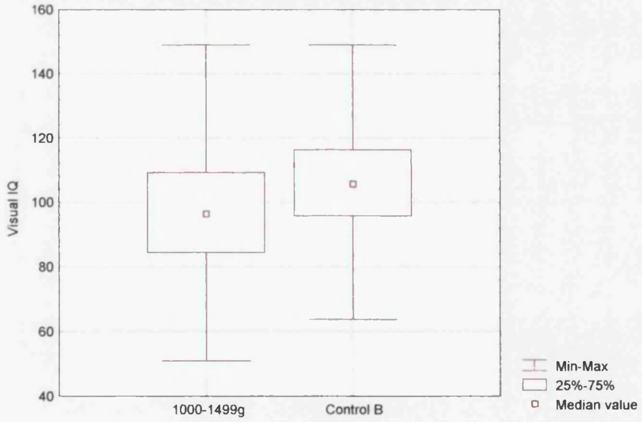

Figure A.2.2.6 *Box and whisker plot for visual IQ by case status (1000-1499g and control B)*

Appendix 3

Low Birthweight Research – Investigation of SGA/AGA Differences

A.3.1 Detailed description of two-way ANOVAs for cognitive sub skills by SGA/AGA status and case

A.3.1.1 Similarities (British Ability Scales)

TABLE A.3.1.1
Differences in mean Similarities scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=47.6	mean=51.9	mean=50.0	mean=49.4
AGA	VLBW	(1)		0.000	0.204	0.572
AGA	control	(2)	0.000		0.298	0.222
SGA	VLBW	(3)	0.204	0.298		0.984
SGA	control	(4)	0.572	0.222	0.984	

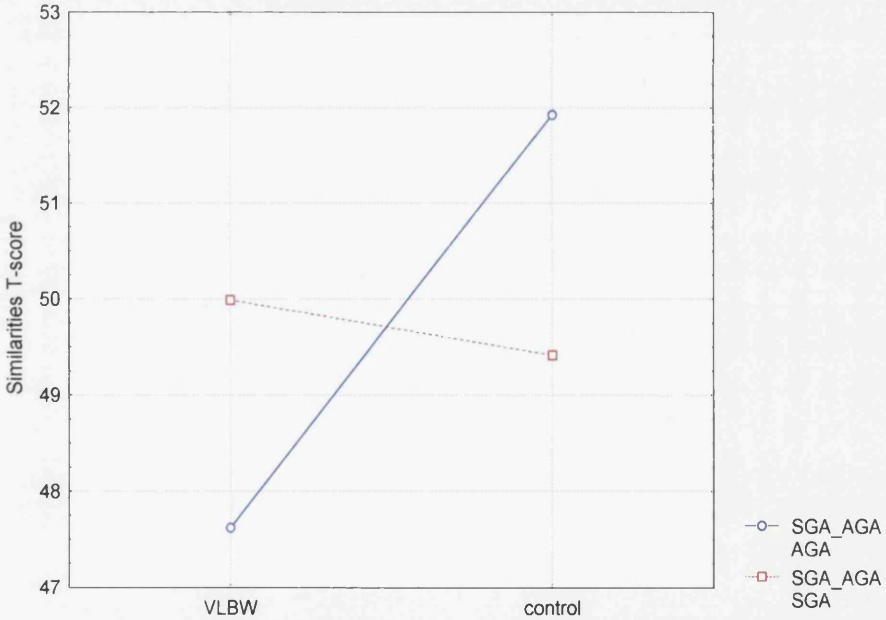

Figure A.3.1.1 *Plot of means (two way interaction) for Similarities by SGA/AGA status and case*

A.3.1.2 Recall of Digits (British Ability Scales)

TABLE A.3.1.2

Differences in mean Recall of Digits scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=48.0	mean=49.9	mean=48.5	mean=46.7
AGA	VLBW	(1)		0.094	0.977	0.761
AGA	control	(2)	0.094		0.589	0.063
SGA	VLBW	(3)	0.977	0.589		0.644
SGA	control	(4)	0.761	0.063	0.644	

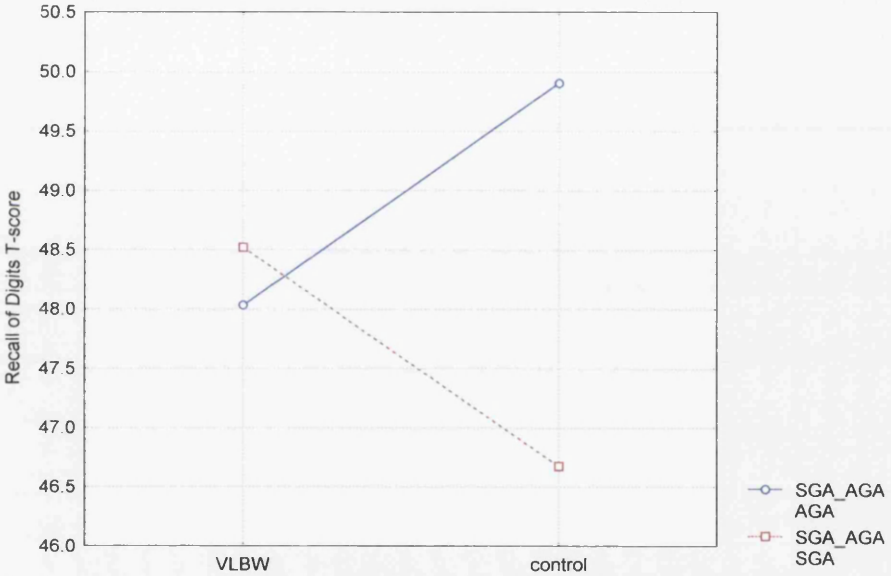

Figure A.3.1.2 *Plot of means (two way interaction) for Recall of Digits by SGA/AGA status and case*

A.3.1.3 Speed of Information Processing (British Ability Scales)

TABLE A.3.1.3
Differences in mean Speed of Information Processing scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=48.0	mean=49.9	mean=48.5	mean=46.7
AGA	VLBW	(1)		0.094	0.977	0.761
AGA	control	(2)	0.094		0.589	0.063
SGA	VLBW	(3)	0.977	0.589		0.644
SGA	control	(4)	0.761	0.063	0.644	

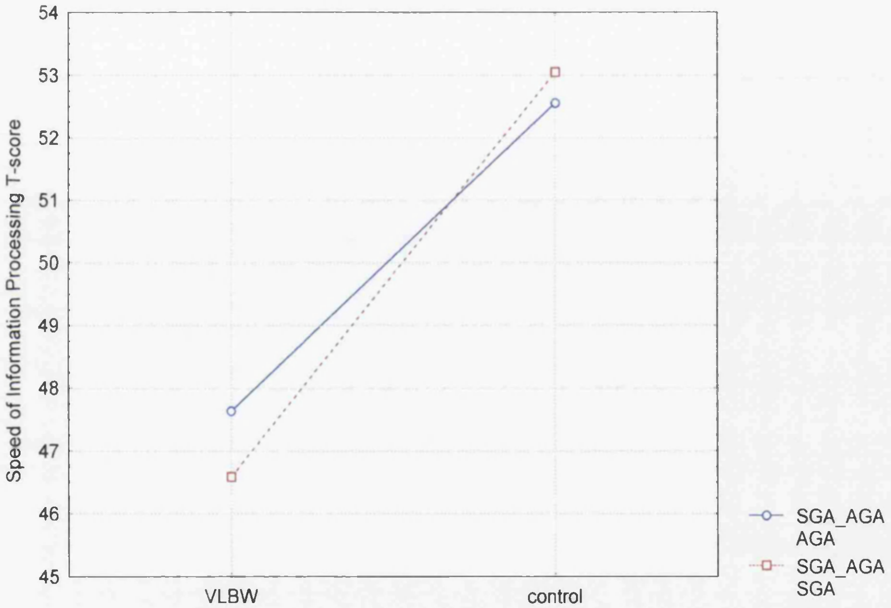

Figure A.3.1.3 *Plot of means (two way interaction) for Speed of Information Processing by SGA/AGA status and case*

A.3.1.4 Block Design (British Ability Scales)

TABLE A.3.1.4
Differences in mean Block Design scores by SGA/AGA status and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=47.3	mean=54.2	mean=47.5	mean=52.7
AGA	VLBW	(1)		0.000	0.998	0.001
AGA	control	(2)	0.000		0.000	0.698
SGA	VLBW	(3)	0.998	0.000		0.011
SGA	control	(4)	0.001	0.698	0.011	

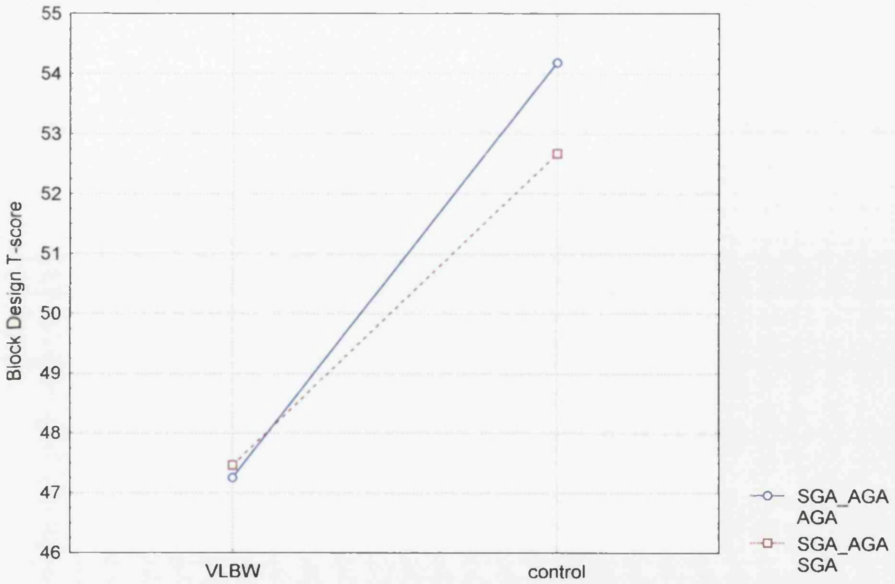

Figure A.3.1.4 *Plot of means (two way interaction) for Block Design by SGA/AGA status and case*

A.3.1.5 Recall of Designs (British Ability Scales)

TABLE A.3.1.5
Differences in mean Recall of Designs scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=50.7	mean=55.8	Mean=51.0	mean=53.5
AGA	VLBW	(1)		0.000	0.997	0.166
AGA	control	(2)	0.000		0.000	0.288
SGA	VLBW	(3)	0.997	0.000		0.345
SGA	control	(4)	0.166	0.288	0.345	

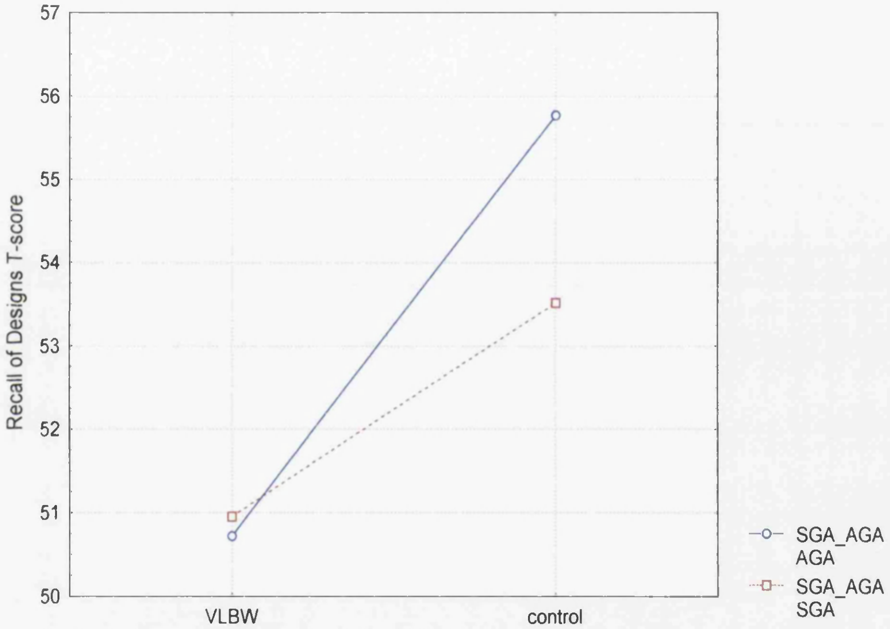

Figure A.3.1.5 *Plot of means (two way interaction) for Recall of Designs by SGA/AGA status and case*

A.3.1.6 Matrices (British Ability Scales)

TABLE A.3.1.6
Differences in mean Matrices scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=45.6	mean=51.0	mean=46.6	mean=48.4
AGA	VLBW	(1)		0.000	0.804	0.142
AGA	control	(2)	0.000		0.000	0.137
SGA	VLBW	(3)	0.804	0.000		0.632
SGA	control	(4)	0.142	0.137	0.632	

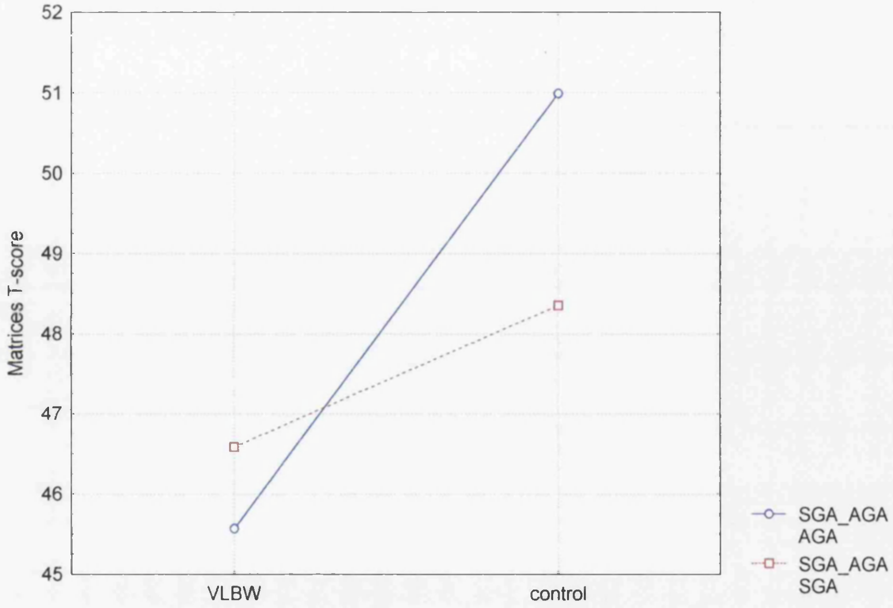

Figure A.3.1.6 *Plot of means (two way interaction) for Matrices by SGA/AGA status and case*

A.3.1.7 Word Definitions (British Ability Scales)

TABLE A.3.1.7
Differences in mean Word Definitions scores by SGA/AGA status and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=39.2	mean=44.6	mean=40.5	mean=41.3
AGA	VLBW	(1)		0.000	0.686	0.402
AGA	control	(2)	0.000		0.001	0.059
SGA	VLBW	(3)	0.686	0.001		0.952
SGA	control	(4)	0.402	0.059	0.952	

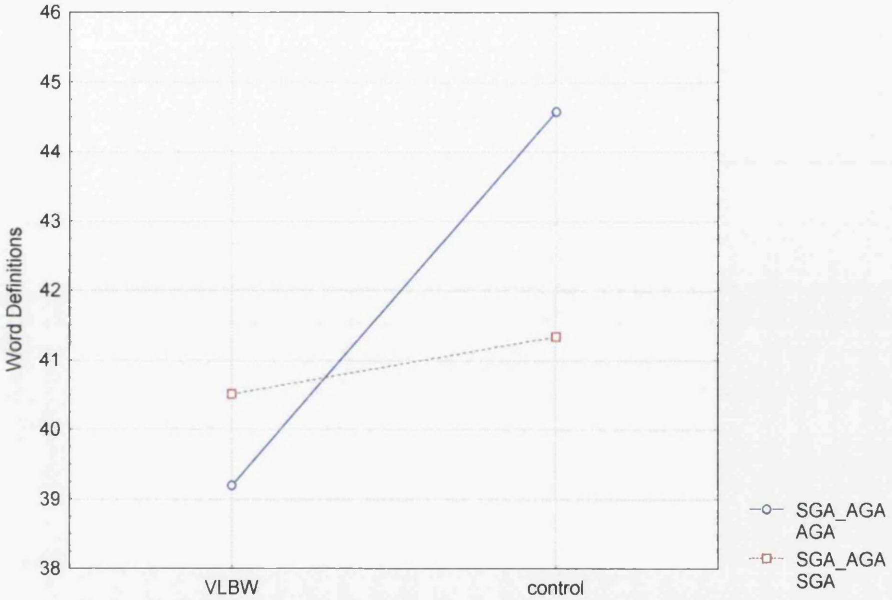

Figure A.3.1.7 Plot of means (two way interaction) for Word Definitions by SGA/AGA status and case

A.3.2 Detailed description of two-way ANOVAs for general IQ, verbal IQ and visual IQ composite scores by SGA/AGA status and case

A.3.2.1.1 General IQ (British Ability Scales)

TABLE A.3.2.1
Differences in mean General IQ scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=92.8	mean=103.0	mean=94.1	mean=98.5
AGA	VLBW	(1)		0.000	0.859	0.011
AGA	control	(2)	0.000		0.000	0.045
SGA	VLBW	(3)	0.859	0.000		0.150
SGA	control	(4)	0.011	0.045	0.150	

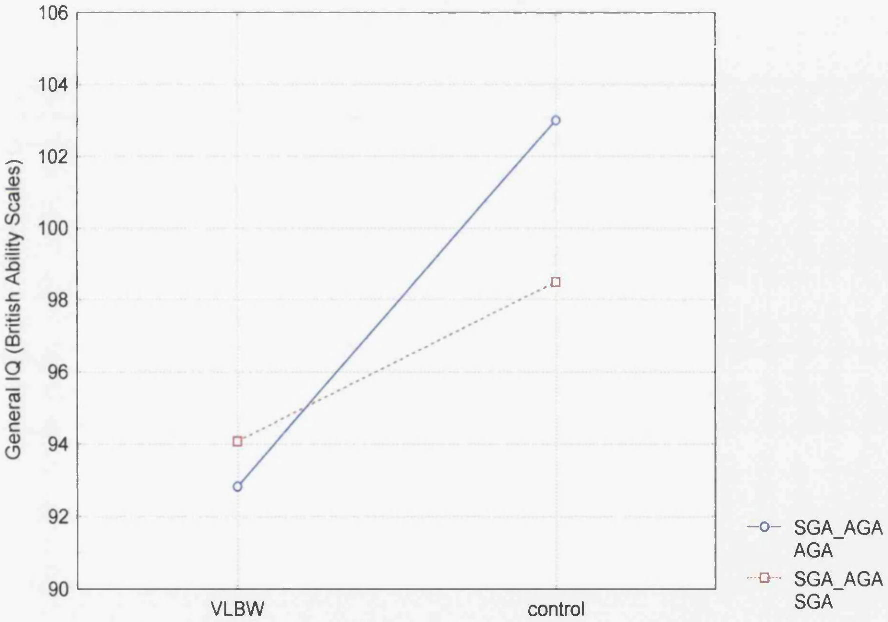

Figure A.3.2.1 Plot of means (two way interaction) for General IQ by SGA/AGA status and case

A.3.2.1.2 Verbal IQ (British Ability Scales)

TABLE A.3.2.2
Differences in mean Verbal IQ scores by SGA/AGA status and case: two-way ANOVA and Tukey HSD post hoc test

			(1) mean=90.8	(2) mean=99.5	(3) mean=92.3	(4) mean=94.9
SGA/AGA	*Case*					
AGA	VLBW	(1)		0.000	0.794	0.148
AGA	control	(2)	0.000		0.000	0.068
SGA	VLBW	(3)	0.794	0.000		0.650
SGA	control	(4)	0.148	0.068	0.650	

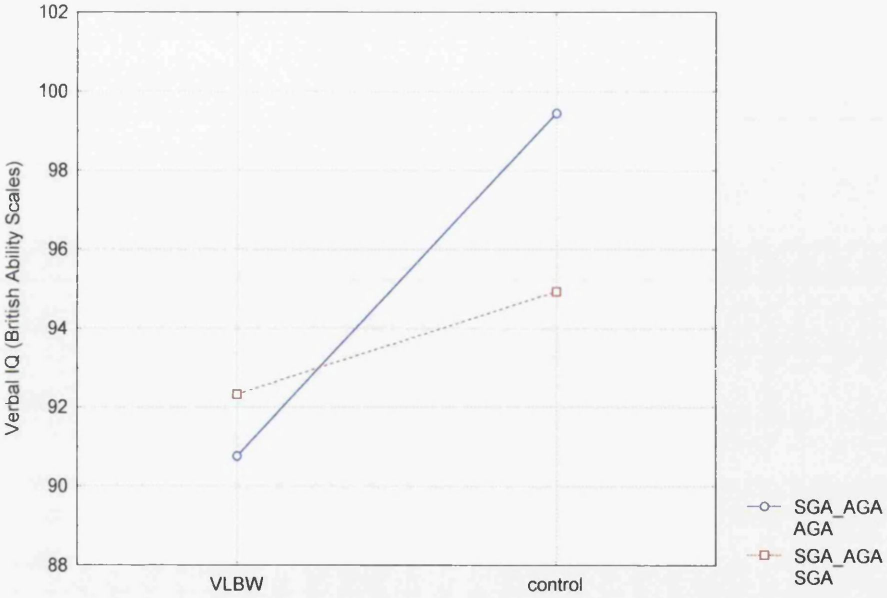

Figure A.3.2.2 *Plot of means (two way interaction) for Verbal IQ by SGA/AGA status and case*

A.3.2.1.3 Visual IQ (British Ability Scales)

TABLE A.3.2.3
Differences in mean Verbal IQ scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=95.4	mean=107.8	mean=96.5	mean=103.2
AGA	VLBW	(1)		0.000	0.953	0.004
AGA	control	(2)	0.000		0.000	0.149
SGA	VLBW	(3)	0.953	0.000		0.046
SGA	control	(4)	0.004	0.149	0.046	

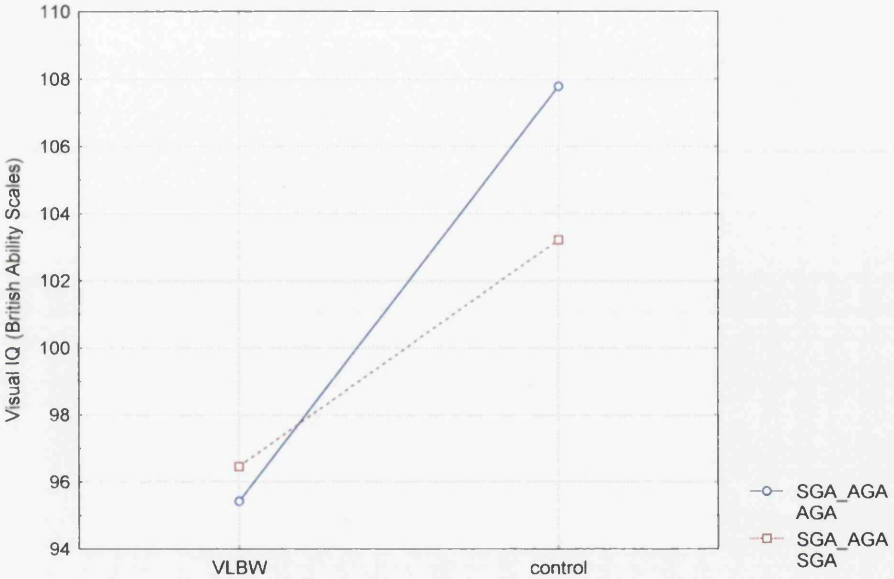

Figure A.3.2.3 *Plot of means (two way interaction) for Visual IQ by SGA/AGA status and case*

A.3.2.2 Detailed description of t-tests for independent samples: differences between mean general IQ, verbal IQ and visual IQ composite scores by SGA/AGA status

A.3.2.2.1 Differences between mean general IQ, verbal IQ and visual IQ composite scores by SGA/AGA status for index group

TABLE A.3.2.2.1

Differences in mean IQ scores (general; verbal; visual) (British Ability Scales) - index (<1500g) children by SGA/AGA status

	VLBW SGA			VLBW AGA								
	N	Mean	SD	N	Mean	SD	t-value	Df	p	Levene F (1, df)	df	p Levene
General IQ	92	94.1	11.8	207	92.8	13.9	0.76	297	>0.05	4.30	297	0.03
Verbal IQ	92	92.3	12.5	207	90.8	14.5	0.89	297	>0.05	2.15	297	0.14
Visual IQ	92	96.5	15.5	208	95.4	17.8	0.48	298	>0.05	5.43	298	0.20

A.3.2.2.2 Differences between mean general IQ, verbal IQ and visual IQ composite scores by SGA/AGA status for comparison group

TABLE A.3.2.2.2
Differences in mean IQ scores (general; verbal; visual) (British Ability Scales) - comparison children by SGA/AGA status

	VLBW SGA			VLBW AGA								
	N	Mean	SD	N	Mean	SD	t-value	Df	p	Levene F (1, df)	df	p Levene
General IQ	62	98.5	12.9	429	103.0	12.3	-2.68	489	<0.01	0.25	489	0.62
Verbal IQ	62	94.9	14.5	429	99.5	13.2	-2.49	489	<0.05	0.20	489	0.65
Visual IQ	62	103.2	14.5	429	107.8	15.1	-2.23	489	<0.05	0.21	489	0.64

A.3.3 Detailed description of two-way ANOVAs for measures of scholastic attainment by SGA/AGA status and case

A.3.3.1 Word Reading (British Ability Scales)

TABLE A.3.3.1
Differences in mean Word Reading scores by SGA/AGA status and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=49.2	mean=54.0	mean=50.6	mean=49.2
AGA	VLBW	(1)		0.000	0.733	1.000
AGA	control	(2)	0.000		0.037	0.007
SGA	VLBW	(3)	0.733	0.037		0.860
SGA	control	(4)	1.000	0.007	0.860	

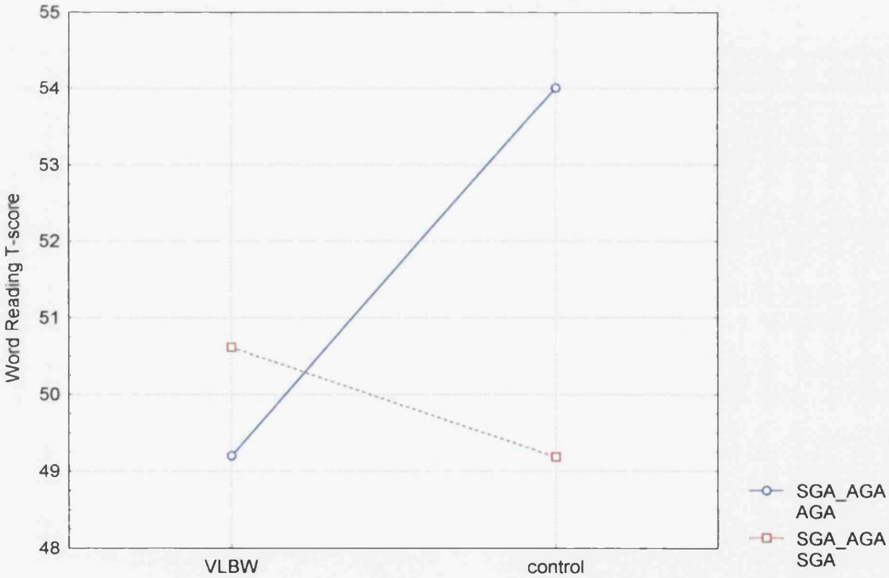

Figure A.3.3.1 *Plot of means (two way interaction) for Word Reading by SGA/AGA status and case*

A.3.3.2 Number Skills (British Ability Scales)

TABLE A.3.3.2
Differences in mean NumberSkills scores by SGA/AGA status and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
SGA/AGA	*Case*		mean=44.5	mean=50.1	mean=43.9	mean=46.6
AGA	VLBW	(1)		0.000	0.968	0.490
AGA	control	(2)	0.000		0.000	0.049
SGA	VLBW	(3)	0.968	0.000		0.381
SGA	control	(4)	0.490	0.049	0.381	

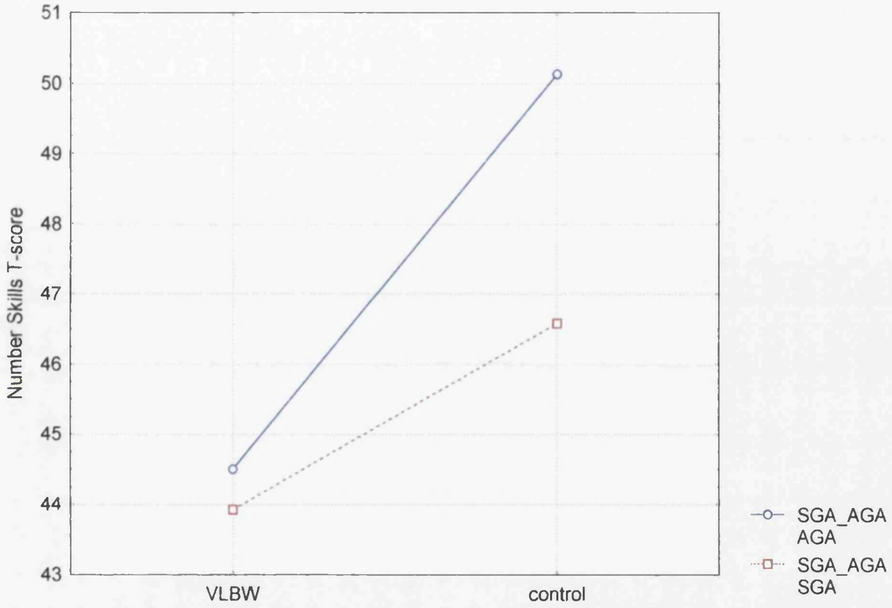

Figure A.3.3.2 *Plot of means (two way interaction) for* Number Skills *by SGA/AGA status and case*

A.3.4 Homogeneity of variance

Levene's test for homogeneity of variance was performed for all the above analyses. No significant results were observed.

Appendix 4

Low Birthweight Research – Investigation of Differences in Neurological Outcome for Index and Comparison Children who were either Small for Gestational Age (SGA) or Appropriate Size for Gestational Age (AGA)

A.4.1 Detailed description of individual items of the Quick Neurological Screening Test by SGA/AGA status – index children and comparison children

The tables on the following pages of Appendix 4 provide information on the index and comparison children's performance on the individual items of the Quick Neurological Screening Test (QNST). Table A.4.1 is a presentation of the proportion of the index children classified as normal, suspicious, abnormal and unable to complete by SGA/AGA status. Table A.4.3 provides the same information, but categorising normal, suspicious, abnormal and unable to complete scores for both groups in neighbouring columns for ease of comparison.

Similarly, table A.4.2 is a presentation of the proportion of the comparison children classified as normal, suspicious, abnormal and unable to complete by SGA/AGA status. Table A.4.4 provides the same information, again categorising normal, suspicious, abnormal and unable to complete scores for both groups in neighbouring columns for ease of comparison.

TABLE A.4.1

Performance on individual items of Quick Neurological Screening Test by SGA/AGA status: index children

	VLBW SGA (N=92)				*VLBW AGA (N=208)*			
	Normal	*Suspicious*	*Abnormal*	*Unable to complete*	*Normal*	*Suspicious*	*Abnormal*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	87 (95)	5 (5)	0 (0)	0 (0)	179 (86)	26 (13)	3 (1)	0 (0)
Figure recognition	61 (66)	27 (30)	4 (4)	0 (0)	120 (58)	77 (37)	11 (5)	0 (0)
Palm form	50 (54)	36 (39)	6 (7)	0 (0)	132 (63)	60 (29)	14 (7)	2 (1)
Eye tracking	69 (75)	18 (20)	5 (5)	0 (0)	168 (81)	25 (12)	15 (7)	0 (0)
Sound patterns	23 (25)	68 (74)	0 (0)	1 (1)	48 (23)	156 (75)	3 (1)	1 (1)
Finger to nose	61 (66)	22 (24)	9 (10)	0 (0)	129 (62)	42 (20)	36 (17)	1 (1)
Thumb and finger circle	56 (61)	33 (36)	1 (1)	2 (2)	131 (63)	61 (29)	15 (7)	1 (1)
Double simultaneous stimulation of hand and cheek	23 (25)	52 (57)	17 (18)	0 (0)	30 (14)	145 (70)	33 (16)	0 (0)
Rapidly reversing repetitive hand movements	39 (43)	42 (46)	10 (11)	1 (1)	59 (28)	111 (53)	37 (18)	1 (1)
Arm and leg extensions	13 (14)	72 (78)	7 (8)	0 (0)	30 (14)	157 (76)	21 (10)	0 (0)
Tandem walk	71 (77)	19 (21)	2 (2)	0 (0)	131 (63)	62 (30)	11 (5)	4 (2)
Standing on one leg	74 (80)	11 (12)	7 (8)	0 (0)	157 (76)	32 (15)	16 (8)	3 (1)
Skipping	84 (92)	5 (5)	3 (3)	0 (0)	185 (89)	18 (9)	2 (1)	3 (1)
Left-right discrimination and hand-eye-foot preference	60 (65)	32 (35)	0 (0)	0 (0)	148 (71)	59 (28)	0 (0)	1 (1)
Behaviour	81 (88)	9 (10)	1 (1)	1 (1)	194 (94)	11 (5)	3 (1)	0 (0)

TABLE A.4.2

Performance on individual items of Quick Neurological Screening Test by SGA/AGA status: comparison children

	Comparison SGA (N=62)				*Comparison AGA (N=429)*			
	Normal	*Suspicious*	*Abnormal*	*Unable to complete*	*Normal*	*Suspicious*	*Abnormal*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	60 (97)	2 (3)	0 (0)	0 (0)	420 (98)	9 (2)	0 (0)	0 (0)
Figure recognition	46 (74)	16 (26)	0 (0)	0 (0)	327 (76)	100 (23)	2 (1)	0 (0)
Palm form	40 (65)	20 (32)	2 (3)	0 (0)	322 (75)	97 (22)	8 (2)	2 (1)
Eye tracking	60 (96)	1 (2)	1 (2)	0 (0)	406 (95)	20 (4)	3 (1)	0 (0)
Sound patterns	23 (37)	39 (63)	0 (0)	0 (0)	214 (50)	210 (49)	5 (1)	0 (0)
Finger to nose	49 (79)	8 (13)	5 (8)	0 (0)	343 (80)	63 (15)	23 (5)	0 (0)
Thumb and finger circle	46 (74)	15 (24)	1 (2)	0 (0)	311 (72)	108 (25)	10 (3)	0 (0)
Double simultaneous stimulation of hand and cheek	15 (24)	40 (65)	7 (11)	0 (0)	123 (29)	260 (61)	46 (11)	0 (0)
Rapidly reversing repetitive hand movements	31 (50)	25 (40)	6 (10)	0 (0)	210 (49)	185 (43)	32 (7)	2 (1)
Arm and leg extensions	24 (39)	35 (56)	3 (5)	0 (0)	160 (37)	265 (62)	4 (1)	0 (0)
Tandem walk	52 (84)	10 (16)	0 (0)	0 (0)	376 (88)	51 (11)	2 (1)	0 (0)
Standing on one leg	58 (94)	2 (3)	2 (3)	0 (0)	406 (94)	21 (5)	2 (1)	0 (0)
Skipping	60 (97)	2 (3)	0 (0)	0 (0)	417(97)	12 (3)	0 (0)	0 (0)
Left-right discrimination and hand-eye-foot preference	46 (74)	16 (26)	0 (0)	0 (0)	330 (77)	99 (23)	0 (0)	0 (0)
Behaviour	61 (98)	1 (2)	0 (0)	0 (0)	422 (98)	5 (1)	2 (1)	0 (0)

Table A.4.3

Performance on individual items of Quick Neurological Screening Test by SGA/AGA status for index children - categorised as normal, suspicious, abnormal and unable to complete

	Index		*Index*		*Index*		*Index*	
	SGA *Normal*	*AGA* *Normal*	*SGA* *Suspicious*	*AGA* *Suspicious*	*SGA* *Abnormal*	*AGA* *Abnormal*	*SGA* *Unable to complete*	*AGA* *Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	87 (95)	179 (86)	5 (5)	26 (13)	0 (0)	3 (1)	0 (0)	0 (0)
Figure recognition	61 (66)	120 (58)	27 (30)	77 (37)	4 (4)	11 (5)	0 (0)	0 (0)
Palm form	50 (54)	132 (63)	36 (39)	60 (29)	6 (7)	14 (7)	0 (0)	2 (1)
Eye tracking	69 (75)	168 (81)	18 (20)	25 (12)	5 (5)	15 (7)	0 (0)	0 (0)
Sound patterns	23 (25)	48 (23)	68 (74)	156 (75)	0 (0)	3 (1)	1 (1)	1 (1)
Finger to nose	61 (66)	129 (62)	22 (24)	42 (20)	9 (10)	36 (17)	0 (0)	1 (1)
Thumb and finger circle	56 (61)	131 (63)	33 (36)	61 (29)	1 (1)	15 (7)	2 (2)	1 (1)
Double simultaneous stimulation of hand and cheek	23 (25)	30 (14)	52 (57)	145 (70)	17 (18)	33 (16)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	39 (43)	59 (28)	42 (46)	111 (53)	10 (11)	37 (18)	1 (1)	1 (1)
Arm and leg extensions	13 (14)	30 (14)	72 (78)	157 (76)	7 (8)	21 (10)	0 (0)	0 (0)
Tandem walk	71 (77)	131 (63)	19 (21)	62 (30)	2 (2)	11 (5)	0 (0)	4 (2)
Standing on one leg	74 (80)	157 (76)	11 (12)	32 (15)	7 (8)	16 (8)	0 (0)	3 (1)
Skipping	84 (92)	185 (89)	5 (5)	18 (9)	3 (3)	2 (1)	0 (0)	3 (1)
Left-right discrimination and hand-eye-foot preference	60 (65)	148 (71)	32 (35)	59 (28)	0 (0)	0 (0)	0 (0)	1 (1)
Behaviour	81 (88)	194 (94)	9 (10)	11 (5)	1 (1)	3 (1)	1 (1)	0 (0)

Table A.4.4

Performance on individual items of Quick Neurological Screening Test by SGA/AGA status for comparison children - categorised as normal, suspicious, abnormal and unable to complete

	Comparison		*Comparison*		*Comparison*		*Comparison*	
	SGA	*AGA*	*SGA*	*AGA*	*SGA*	*AGA*	*SGA*	*AGA*
	Normal	*Normal*	*Suspicious*	*Suspicious*	*Abnormal*	*Abnormal*	*Unable to complete*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	60 (97)	420 (98)	2 (3)	9 (2)	0 (0)	0 (0)	0 (0)	0 (0)
Figure recognition	46 (74)	327 (76)	16 (26)	100 (23)	0 (0)	2 (1)	0 (0)	0 (0)
Palm form	40 (65)	322 (75)	20 (32)	97 (22)	2 (3)	8 (2)	0 (0)	2 (1)
Eye tracking	60 (96)	406 (95)	1 (2)	20 (4)	1 (2)	3 (1)	0 (0)	0 (0)
Sound patterns	23 (37)	214 (50)	39 (63)	210 (49)	0 (0)	5 (1)	0 (0)	0 (0)
Finger to nose	49 (79)	343 (80)	8 (13)	63 (15)	5 (8)	23 (5)	0 (0)	0 (0)
Thumb and finger circle	46 (74)	311 (72)	15 (24)	108 (25)	1 (2)	10 (3)	0 (0)	0 (0)
Double simultaneous stimulation of hand and cheek	15 (24)	123 (29)	40 (65)	260 (61)	7 (11)	46 (11)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	31 (50)	210 (49)	25 (40)	185 (43)	6 (10)	32 (7)	0 (0)	2 (1)
Arm and leg extensions	24 (39)	160 (37)	35 (56)	265 (62)	3 (5)	4 (1)	0 (0)	0 (0)
Tandem walk	52 (84)	376 (88)	10 (16)	51 (11)	0 (0)	2 (1)	0 (0)	0 (0)
Standing on one leg	58 (94)	406 (94)	2 (3)	21 (5)	2 (3)	2 (1)	0 (0)	0 (0)
Skipping	60 (97)	417(97)	2 (3)	12 (3)	0 (0)	0 (0)	0 (0)	0 (0)
Left-right discrimination and hand-eye-foot preference	46 (74)	330 (77)	16 (26)	99 (23)	0 (0)	0 (0)	0 (0)	0 (0)
Behaviour	61 (98)	422 (98)	1 (2)	5 (1)	0 (0)	2 (1)	0 (0)	0 (0)

Appendix 5

Low Birthweight Research – Investigation of Gender Differences

A.5.1 Detailed description of two-way ANOVAs for cognitive sub skills by gender and case

A.5.1.1 Similarities (British Ability Scales)

TABLE A.5.1.1

Differences in mean Similarities scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		48.7	48.0	50.8	51.0
VLBW	Female	(1)		0.897	0.157	0.092
VLBW	Male	(2)	0.897		0.216	0.010
control	Female	(3)	0.157	0.022		0.990
control	Male	(4)	0.0912	0.010	0.990	

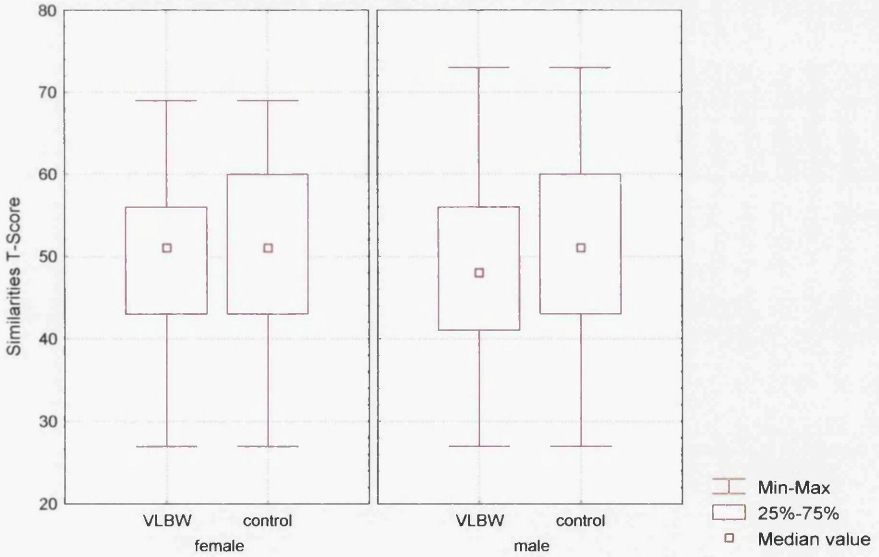

Figure A.5.1.1 *Categorised box and whisker plot for Similarities (BAS) by gender and case*

A.5.1.2 Recall of Digits (British Ability Scales)

TABLE A.5.1.2

Differences in mean Recall of Digits scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		48.1	48.3	49.7	48.3
VLBW	Female	(1)		1.00	0.36	1.00
VLBW	Male	(2)	1.00		0.46	1.00
control	Female	(3)	0.36	0.46		0.33
control	Male	(4)	1.00	1.00	0.33	

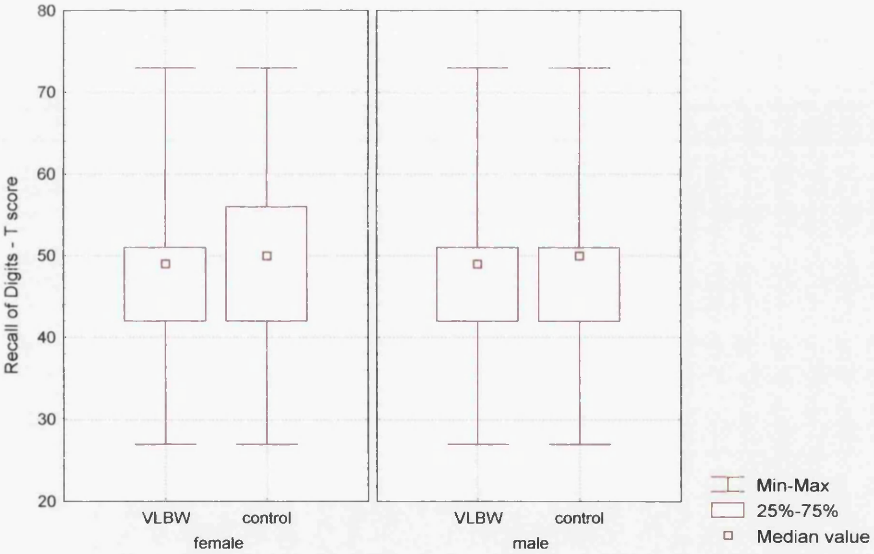

Figure A.5.1.2 *Categorised box and whisker plot for Recall of Digits (BAS) by gender and case*

A.5.1.3 Speed of Information Processing (British Ability Scales)

TABLE A.5.1.3

Differences in mean Speed of Information Processing scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		47.3	47.3	51.8	52.7
VLBW	Female	(1)		1.00	0.00	0.00
VLBW	Male	(2)	1.00		0.00	0.00
control	Female	(3)	0.00	0.00		0.70
control	Male	(4)	0.00	0.00	0.70	

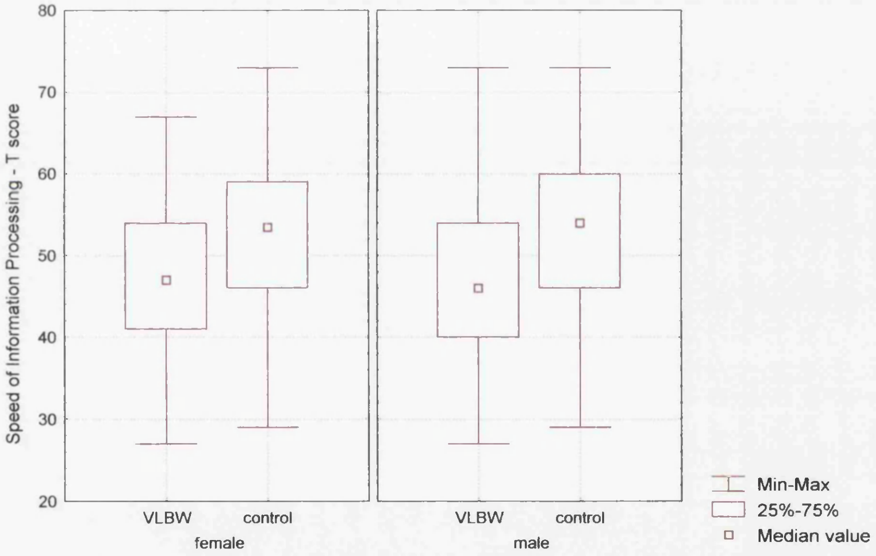

Figure A.5.1.3 *Categorised box and whisker plot for Speed of Information Processing (BAS) by gender and case*

A.5.1.4 Block Design (British Ability Scales)

TABLE A.5.1.4

Differences in mean Block Design scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		46.9	47.8	53.2	53.9
VLBW	female	(1)		0.88	0.00	0.00
VLBW	Male	(2)	0.88		0.00	0.00
control	Female	(3)	0.00	0.00		0.87
control	Male	(4)	0.00	0.00	0.87	

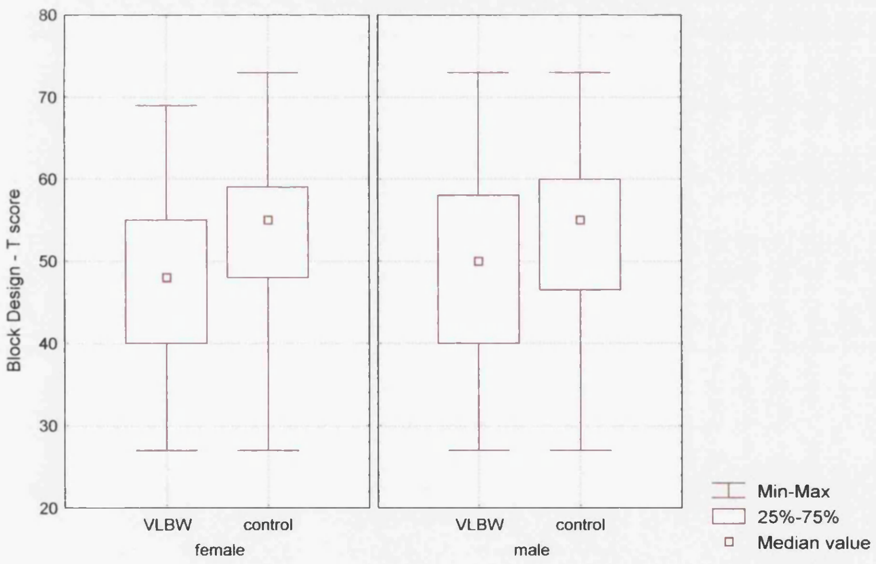

Figure A.5.1.4 *Categorised box and whisker plot for Block Design (BAS) by gender and case*

A.5.1.5 Recall of Designs (British Ability Scales)

TABLE A.5.1.5

Differences in mean Recall of Designs scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		49.8	51.8	55.3	55.6
VLBW	female	(1)		0.25	0.00	0.00
VLBW	male	(2)	0.25		0.00	0.00
control	female	(3)	0.00	0.00		0.97
control	male	(4)	0.00	0.00	0.97	

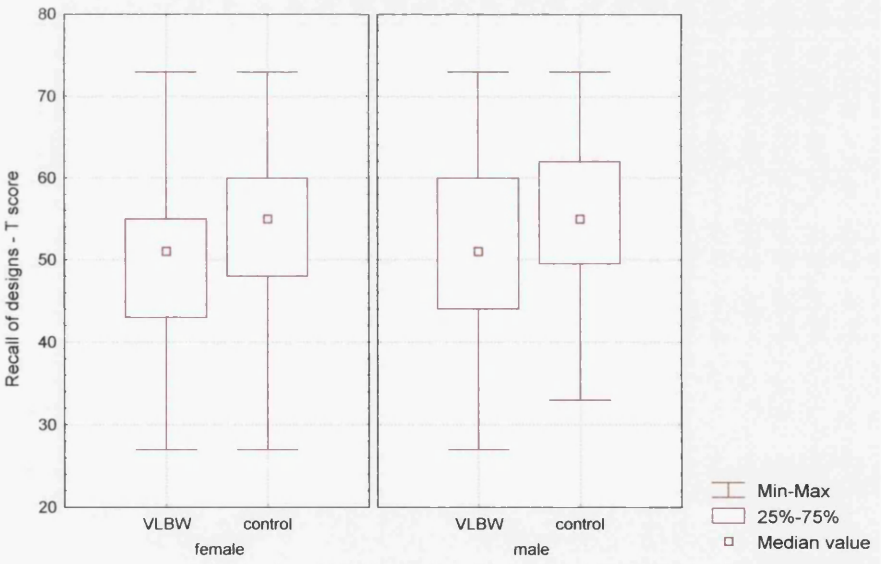

Figure A.5.1.5 *Categorised box and whisker plot for Recall of Designs (BAS) by gender and case*

A.5.1.6 Matrices (British Ability Scales)

TABLE A.5.1.6

Differences in mean Matrices scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		46.1	45.7	50.6	49.4
VLBW	female	(1)		0.98	0.00	0.00
VLBW	male	(2)	0.25		0.00	0.00
control	female	(3)	0.00	0.00		0.36
control	male	(4)	0.00	0.00	0.36	

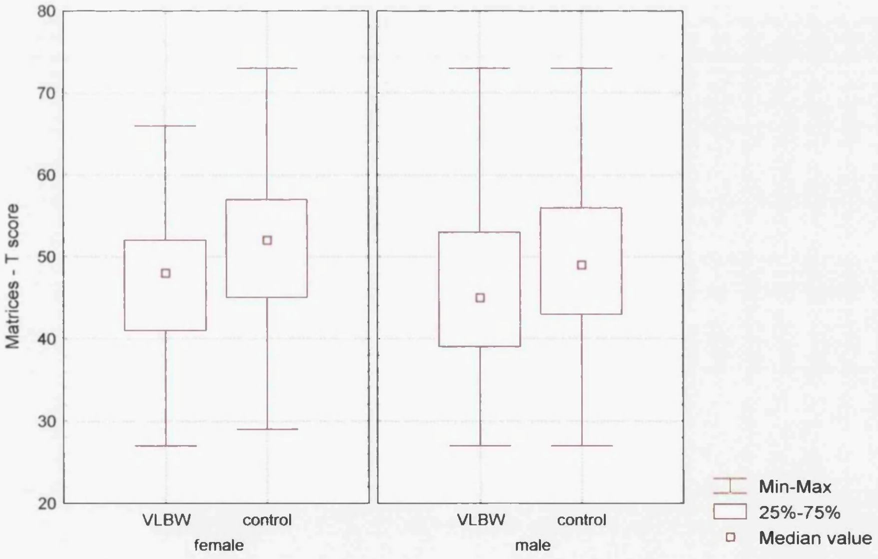

Figure A.5.1.6 *Categorised box and whisker plot forMatrices (BAS) by gender and case*

A.5.1.7 Word Definitions (British Ability Scales)

TABLE A.5.1.7

Differences in mean Word Definitions scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		38.9	40.4	43.2	43.0
VLBW	female	(1)		0.52	0.00	0.00
VLBW	male	(2)	0.52		0.15	0.30
control	female	(3)	0.00	0.15		0.99
control	male	(4)	0.00	0.30	0.99	

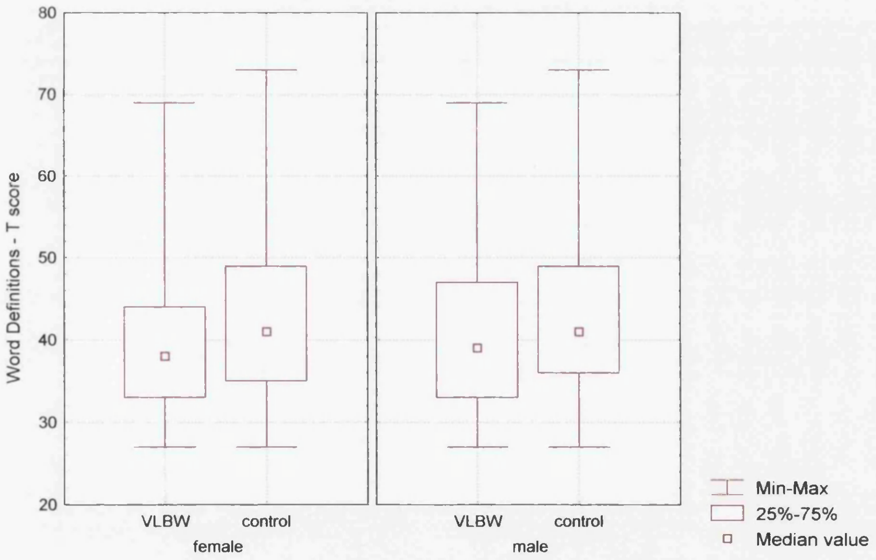

Figure A.5.1.7 *Categorised box and whisker plot for Word Definitions (BAS) by gender and case*

A.5.2 Detailed description of two-way ANOVAs for general IQ, verbal IQ and visual IQ composite scores by gender and case status

A.5.2.1 General IQ (British Ability Scales)

TABLE A.5.2.1

Differences in mean General IQ scores by gender and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		92.7	93.7	101.4	101.2
VLBW	female	(1)		0.92	0.00	0.00
VLBW	male	(2)	0.92		0.00	0.00
control	female	(3)	0.00	0.00		1.00
control	male	(4)	0.00	0.00	1.00	

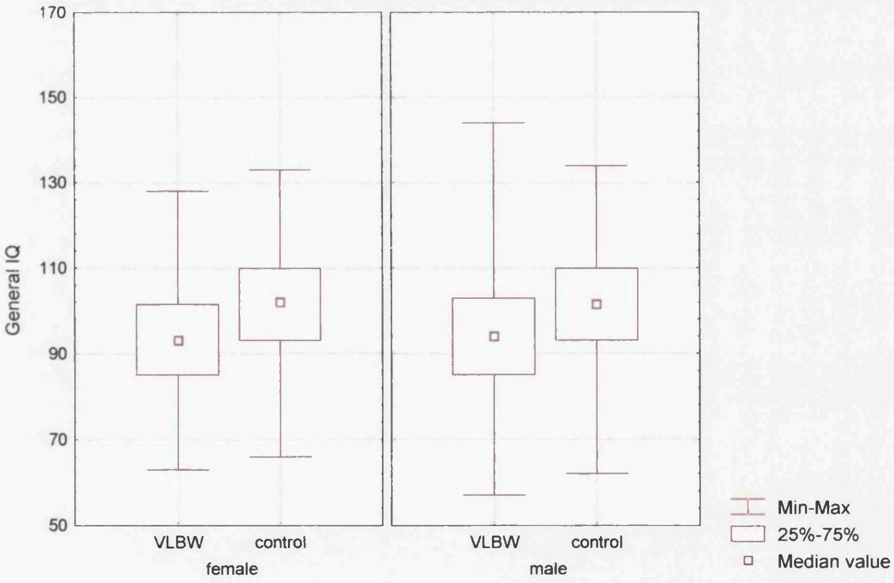

Figure A.5.2.1 *Categorised box and whisker plot for General IQ (BAS) by gender and case*

A.5.2.2 Verbal IQ (British Ability Scales)

TABLE A.5.2.2

Differences in mean Verbal IQ scores by gender and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		91.1	91.4	97.5	97.3
VLBW	female	(1)		1.00	0.00	0.00
VLBW	male	(2)	1.00		0.00	0.00
control	female	(3)	0.00	0.00		1.00
control	male	(4)	0.00	0.00	1.00	

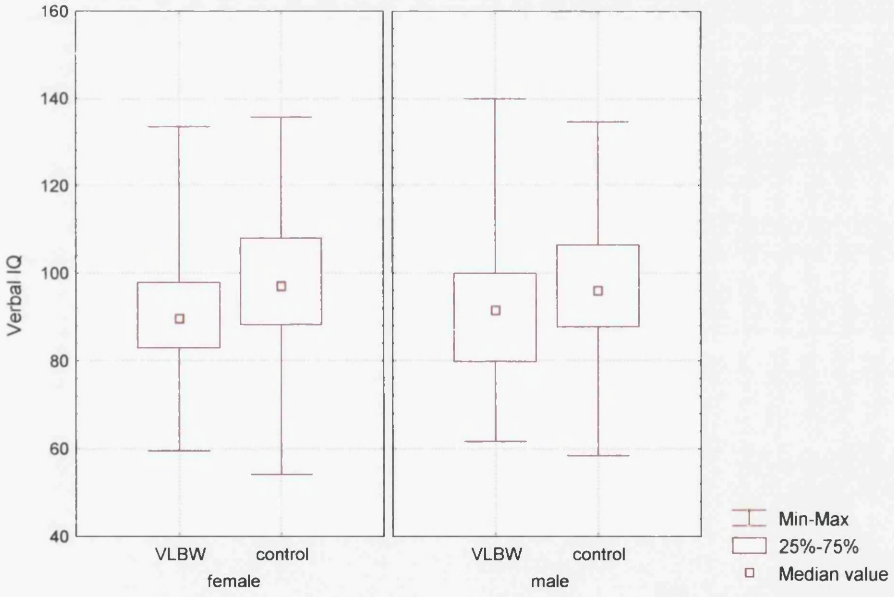

Figure A.5.2.2 *Categorised box and whisker plot for Verbal IQ (BAS) by gender and case*

A.5.2.3 Visual IQ (British Ability Scales)

TABLE A.5.2.3

Differences in mean Visual IQ scores by gender and case: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		94.9	96.6	106.5	106.3
VLBW	female	(1)		0.77	0.00	0.00
VLBW	male	(2)	0.77		0.00	0.00
control	female	(3)	0.00	0.00		1.00
control	male	(4)	0.00	0.00	1.00	

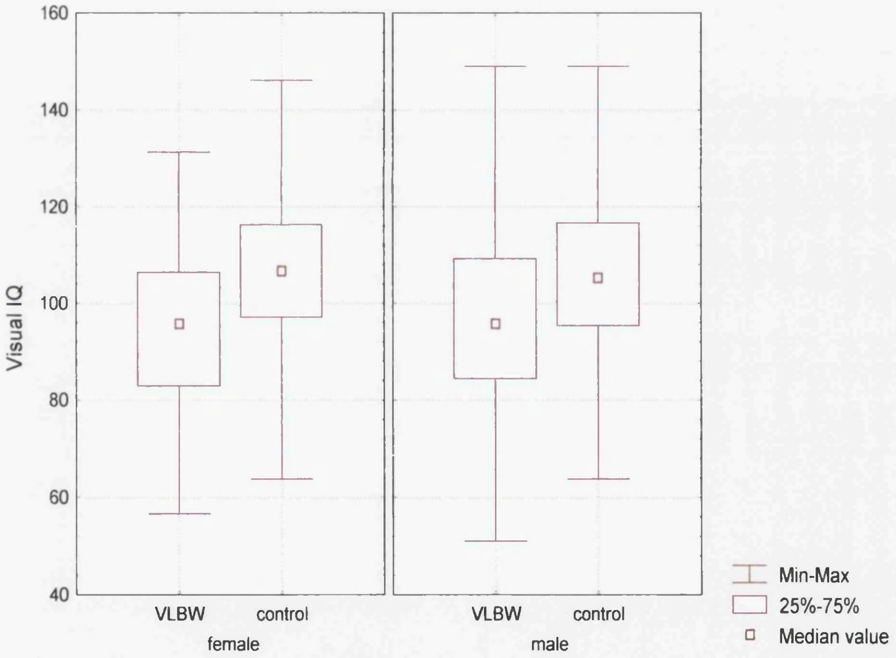

Figure A.5.2.3 *Categorised box and whisker plot for Visual IQ (BAS) by gender and case*

A.5.3 Detailed description of two-way ANOVAs for measures of scholastic attainment

A.5.3.1 Word Reading (British Ability Scales)

TABLE A.5.3.1

Differences in mean Word Reading scores by gender and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		49.5	49.8	52.7	52.7
VLBW	female	(1)		1.00	0.02	0.02
VLBW	male	(2)	1.00		0.04	0.04
control	female	(3)	0.02	0.04		1.00
control	male	(4)	0.02	0.04	1.00	

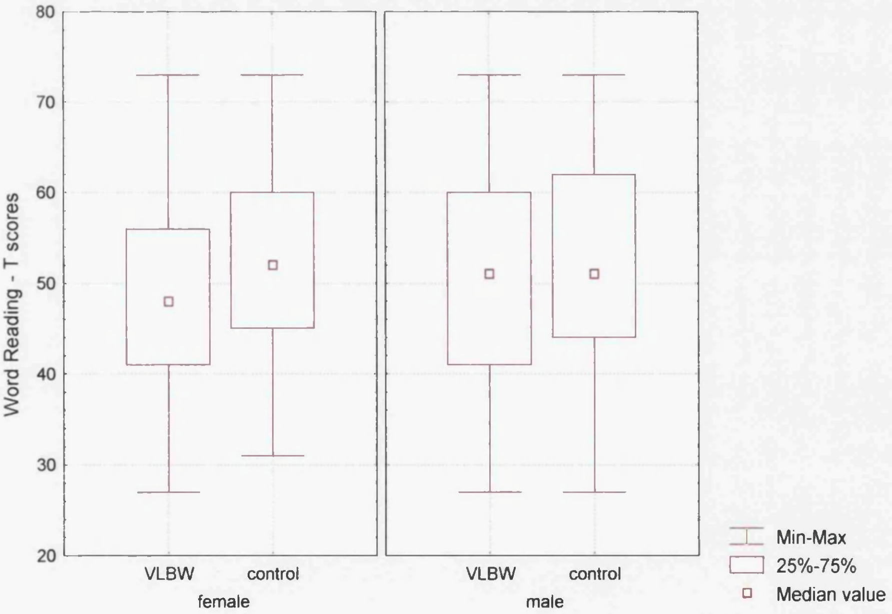

Figure A.5.3.1 Categorised box and whisker plot for Word Reading (BAS) by gender and case

A.5.3.2 Number Skills (British Ability Scales)

TABLE A.5.3.2

Differences in mean Number Skills scores by gender and case: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
Case	*Gender*		44.2	44.5	50.2	48.1
VLBW	female	(1)		1.00	0.00	0.00
VLBW	male	(2)	1.00		0.00	0.00
control	female	(3)	0.00	0.00		0.05
control	male	(4)	0.00	0.00	0.05	

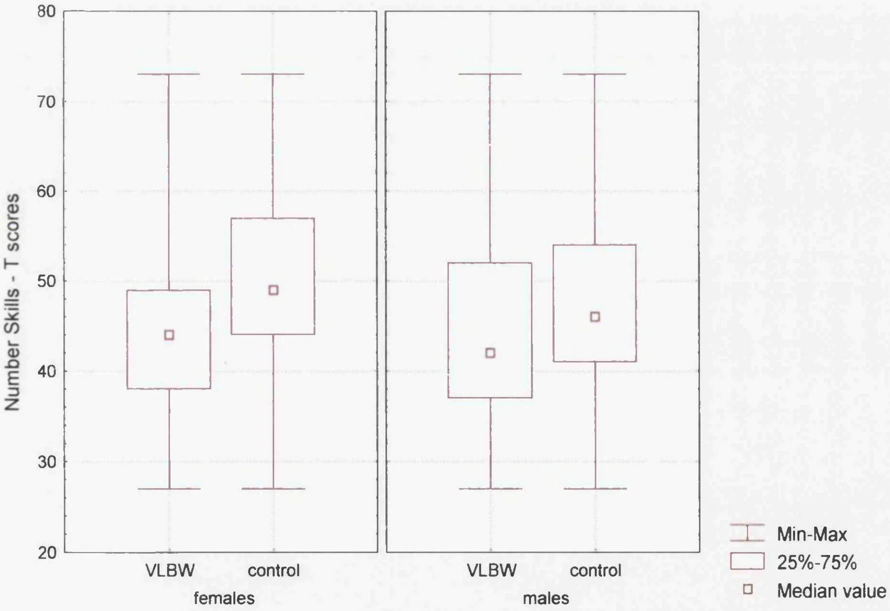

Figure A.5.3.2 *Categorised box and whisker plot for Number Skills (BAS) by gender and case*

A.5.3 Homogeneity of variance

Levene's test for homogeneity of variance was performed for all the above analyses. No significant results were observed.

Appendix 6

Low Birthweight Research – Investigation of Gender Differences in Neurological Outcome for Index and Comparison Children

A.6.1 Detailed description of individual items of the Quick Neurological Screening Test by gender – index children and comparison children

The tables on the following pages of Appendix 5 provide information on the index and comparison children's performance on the individual items of the Quick Neurological Screening Test (QNST). Table A.6.1 is a presentation of the proportion of the index children classified as normal, suspicious, abnormal and unable to complete by gender. Table A.6.3 provides the same information, but categorising normal, suspicious, abnormal and unable to complete scores for both groups in neighbouring columns for ease of comparison.

Similarly, table A.6.2 is a presentation of the proportion of the comparison children classified as normal, suspicious, abnormal and unable to complete by gender. Table A.6.4 provides the same information, again categorising normal, suspicious, abnormal and unable to complete scores for both groups in neighbouring columns for ease of comparison.

TABLE A.6.1

Performance on individual items of Quick Neurological Screening Test by gender: index children

	VLBW Female (N=153)				*VLBW Male (N=147)*			
	Normal	*Suspicious*	*Abnormal*	*Unable to complete*	*Normal*	*Suspicious*	*Abnormal*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	144 (94)	9 (6)	0 (0)	0 (0)	122 (83)	22 (15)	3 (2)	0 (0)
Figure recognition	95 (62)	49 (32)	9 (6)	0 (0)	86 (59)	55 (37)	6 (4)	0 (0)
Palm form	103 (67)	40 (26)	9 (6)	1 (1)	79 (54)	56 (38)	11 (7)	1 (1)
Eye tracking	130 (85)	19 (12)	4 (3)	0 (0)	107 (73)	24 (16)	16 (11)	0 (0)
Sound patterns	39 (26)	112 (73)	0 (0)	2 (1)	32 (22)	112 (76)	3 (2)	0 (0)
Finger to nose	109 (71)	24 (16)	20 (13)	0 (0)	81 (55)	40 (27)	25 (17)	1 (1)
Thumb and finger circle	100 (66)	48 (31)	5 (3)	0 (0)	87 (59)	46 (32)	11 (7)	3 (2)
Double simultaneous stimulation of hand and cheek	33 (22)	95 (62)	25 (16)	0 (0)	20 (14)	102 (69)	25 (17)	0 (0)
Rapidly reversing repetitive hand movements	55 (36)	81 (53)	17 (11)	0 (0)	43 (29)	72 (49)	30 (20)	2 (2)
Arm and leg extensions	24 (16)	122 (80)	7 (4)	0 (0)	19 (13)	107 (73)	21 (14)	0 (0)
Tandem walk	104 (68)	43 (28)	5 (3)	1 (1)	98 (67)	38 (26)	8 (5)	3 (2)
Standing on one leg	119 (77)	24 (16)	9 (6)	1 (1)	112 (76)	19 (13)	14 (9)	2 (2)
Skipping	149 (97)	3 (2)	0 (0)	1 (1)	120 (81)	20 (14)	5 (3)	2 (2)
Left-right discrimination and hand-eye-foot preference	98 (64)	55 (36)	0 (0)	0 (0)	110 (75)	36 (24)	0 (0)	1 (1)
Behaviour	144 (94)	6 (4)	3 (2)	0 (0)	131 (89)	14 (9)	1 (1)	1 (1)

TABLE A.6.2

Performance on individual items of Quick Neurological Screening Test by gender: comparison children

	Comparison Female (N=298)				*Comparison Male (N=292)*			
	Normal	*Suspicious*	*Abnormal*	*Unable to complete*	*Normal*	*Suspicious*	*Abnormal*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	292 (98)	6 (2)	0 (0)	0 (0)	284 (97)	8 (3)	0 (0)	0 (0)
Figure recognition	225 (76)	70 (23)	3 (1)	0 (0)	222 (76)	70 (24)	0 (0)	0 (0)
Palm form	246 (83)	48 (16)	3 (1)	1 (0.3)	185 (63)	98 (34)	8 (3)	1 (0.3)
Eye tracking	287 (96)	11 (4)	0 (0)	0 (0)	271 (93)	16 (5)	5 (2)	0 (0)
Sound patterns	152 (51)	143 (48)	3 (1)	0 (0)	123 (42)	166 (57)	3 (1)	0 (0)
Finger to nose	247 (83)	35 (12)	16 (5)	0 (0)	226 (77)	47 (16)	19 (7)	0 (0)
Thumb and finger circle	229 (77)	67 (22)	2 (1)	0 (0)	200 (68)	82 (28)	10 (4)	0 (0)
Double simultaneous stimulation of hand and cheek	82 (28)	180 (60)	36 (12)	0 (0)	82 (28)	180 (62)	30 (10)	0 (0)
Rapidly reversing repetitive hand movements	150 (50)	129 (43)	18 (6)	1 (0.3)	133 (46)	129 (44)	29 (10)	1 (0.3)
Arm and leg extensions	117 (39)	177 (60)	4 (1)	0 (0)	105 (36)	182 (62)	5 (2)	0 (0)
Tandem walk	265 (89)	31 (10)	2 (1)	0 (0)	253 (87)	39 (13)	0 (0)	0 (0)
Standing on one leg	282 (95)	15 (5)	1 (0.3)	0 (0)	272 (93)	15 (5)	5 (2)	0 (0)
Skipping	295 (99)	3 (1)	0 (0)	0 (0)	274 (94)	17 (6)	1 (0.3)	0 (0)
Left-right discrimination and hand-eye-foot preference	220 (74)	78 (26)	0 (0)	0 (0)	225 (77)	67 (23)	0 (0)	0 (0)
Behaviour	292 (98)	5 (2)	1 (0.3)	0 (0)	285 (98)	4 (1)	3 (1)	0 (0)

Table A.6.3

Performance on individual items of Quick Neurological Screening Test by gender for index children - categorised as normal, suspicious, abnormal and unable to complete

	Index		*Index*		*Index*		*Index*	
	Female Normal	*Male Normal*	*Female Suspicious*	*Male Suspicious*	*Female Abnormal*	*Male Abnormal*	*Female Unable to complete*	*Male Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	144 (94)	122 (83)	9 (6)	22 (15)	0 (0)	3 (2)	0 (0)	0 (0)
Figure recognition	95 (62)	86 (59)	49 (32)	55 (37)	9 (6)	6 (4)	0 (0)	0 (0)
Palm form	103 (67)	79 (54)	40 (26)	56 (38)	9 (6)	11 (7)	1 (1)	1 (1)
Eye tracking	130 (85)	107 (73)	19 (12)	24 (16)	4 (3)	16 (11)	0 (0)	0 (0)
Sound patterns	39 (26)	32 (22)	112 (73)	112 (76)	0 (0)	3 (2)	2 (1)	0 (0)
Finger to nose	109 (71)	81 (55)	24 (16)	40 (27)	20 (13)	25 (17)	0 (0)	1 (1)
Thumb and finger circle	100 (66)	87 (59)	48 (31)	46 (32)	5 (3)	11 (7)	0 (0)	3 (2)
Double simultaneous stimulation of hand and cheek	33 (22)	20 (14)	95 (62)	102 (69)	25 (16)	25 (17)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	55 (36)	43 (29)	81 (53)	72 (49)	17 (11)	30 (20)	0 (0)	2 (2)
Arm and leg extensions	24 (16)	19 (13)	122 (80)	107 (73)	7 (4)	21 (14)	0 (0)	0 (0)
Tandem walk	104 (68)	98 (67)	43 (28)	38 (26)	5 (3)	8 (5)	1 (1)	3 (2)
Standing on one leg	119 (77)	112 (76)	24 (16)	19 (13)	9 (6)	14 (9)	1 (1)	2 (2)
Skipping	149 (97)	120 (81)	3 (2)	20 (14)	0 (0)	5 (3)	1 (1)	2 (2)
Left-right discrimination and hand-eye-foot preference	98 (64)	110 (75)	55 (36)	36 (24)	0 (0)	0 (0)	0 (0)	1 (1)
Behaviour	144 (94)	131 (89)	6 (4)	14 (9)	3 (2)	1 (1)	0 (0)	1 (1)

Table A.6.4

Performance on individual items of Quick Neurological Screening Test by gender for comparison children - categorised as normal, suspicious, abnormal and unable to complete

	Comparison		*Comparison*		*Comparison*		*Comparison*	
	Female Normal	*Male Normal*	*Female Suspicious*	*Male Suspicious*	*Female Abnormal*	*Male Abnormal*	*Female Unable to complete*	*Male Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	292 (98)	284 (97)	6 (2)	8 (3)	0 (0)	0 (0)	0 (0)	0 (0)
Figure recognition	225 (76)	222 (76)	70 (23)	70 (24)	3 (1)	0 (0)	0 (0)	0 (0)
Palm form	246 (83)	185 (63)	48 (16)	98 (34)	3 (1)	8 (3)	1 (0.3)	1 (0.3)
Eye tracking	287 (96)	271 (93)	11 (4)	16 (5)	0 (0)	5 (2)	0 (0)	0 (0)
Sound patterns	152 (51)	123 (42)	143 (48)	166 (57)	3 (1)	3 (1)	0 (0)	0 (0)
Finger to nose	247 (83)	226 (77)	35 (12)	47 (16)	16 (5)	19 (7)	0 (0)	0 (0)
Thumb and finger circle	229 (77)	200 (68)	67 (22)	82 (28)	2 (1)	10 (4)	0 (0)	0 (0)
Double simultaneous stimulation of hand and cheek	82 (28)	82 (28)	180 (60)	180 (62)	36 (12)	30 (10)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	150 (50)	133 (46)	129 (43)	129 (44)	18 (6)	29 (10)	1 (0.3)	1 (0.3)
Arm and leg extensions	117 (39)	105 (36)	177 (60)	182 (62)	4 (1)	5 (2)	0 (0)	0 (0)
Tandem walk	265 (89)	253 (87)	31 (10)	39 (13)	2 (1)	0 (0)	0 (0)	0 (0)
Standing on one leg	282 (95)	272 (93)	15 (5)	15 (5)	1 (0.3)	5 (2)	0 (0)	0 (0)
Skipping	295 (99)	274 (94)	3 (1)	17 (6)	0 (0)	1 (0.3)	0 (0)	0 (0)
Left-right discrimination and hand-eye-foot preference	220 (74)	225 (77)	78 (26)	67 (23)	0 (0)	0 (0)	0 (0)	0 (0)
Behaviour	292 (98)	285 (98)	5 (2)	4 (1)	1 (0.3)	3 (1)	0 (0)	0 (0)

Appendix 7

Low Birthweight Research – Investigation of Differences in Neurological Outcome for Index and Comparison Children by Birthweight Groupings (<1000g and 1000-1499g)

A.7.1 Detailed description of individual items of the Quick Neurological Screening Test by birthweight groupings – index children and comparison children

The tables on the following pages of Appendix 6 provide information on the index and comparison children's performance on the individual items of the Quick Neurological Screening Test (QNST). Table A.7.1 is a presentation of the proportion of the index children (<1000g) and their matched classroom peers classified as normal, suspicious, abnormal and unable to complete. Table A.7.3 provides the same information, but categorising normal, suspicious, abnormal and unable to complete scores for both groups in neighbouring columns for ease of comparison.

Similarly, table A.7.2 is a presentation of the proportion of the comparison children (1000-1499g) and their matched classroom peers classified as normal, suspicious, abnormal and unable to complete. Table A.7.4 provides the same information, again categorising normal, suspicious, abnormal and unable to complete scores for both groups in neighbouring columns for ease of comparison.

An additional table, A.7.5 presents the performance on the individual items of the QNST categorised as normal, suspicious, Abnormal or unable to complete by the two index groups (<1000g and 1000-1499g) in neighbouring columns for ease of comparison.

TABLE A.7.1
Performance on individual items of Quick Neurological Screening Test by birthweight grouping: index children (<1000g) and matched classroom peers

	VLBW <1000g				*Comparison A*			
	(N=45)				*(N=90)*			
	Normal	*Suspicious*	*Abnormal*	*Unable to complete*	*Normal*	*Suspicious*	*Abnormal*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	35 (78)	9 (20)	1 (2)	0 (0)	89 (99)	1 (1)	0 (0)	0 (0)
Figure recognition	20 (44.5)	20 (44.5)	5 (11)	0 (0)	80 (89)	10 (11)	0 (0)	0 (0)
Palm form	24 (54)	18 (40)	2 (4)	1 (2)	74 (82)	14 (16)	1 (1)	1 (1)
Eye tracking	32 (71)	8 (18)	5 (11)	0 (0)	87 (97)	2 (2)	1 (1)	0 (0)
Sound patterns	10 (23)	33 (73)	1 (2)	1 (2)	40 (45)	48 (53)	2 (2)	0 (0)
Finger to nose	23 (51)	12 (27)	10 (22)	0 (0)	74 (82)	12 (13)	4 (5)	0 (0)
Thumb and finger circle	24 (53)	15 (34)	5 (11)	1 (2)	69 (77)	21 (23)	0 (0)	0 (0)
Double simultaneous stimulation of hand and cheek	7 (16)	33 (73)	5 (11)	0 (0)	24 (27)	57 (63)	9 (10)	0 (0)
Rapidly reversing repetitive hand movements	7 (16)	26 (58)	11 (24)	1 (2)	47 (52)	35 (39)	7 (8)	1 (1)
Arm and leg extensions	3 (7)	33 (73)	9 (20)	0 (0)	44 (49)	46 (51)	0 (0)	0 (0)
Tandem walk	29 (65)	10 (22)	5 (11)	1 (2)	81 (90)	9 (10)	0 (0)	0 (0)
Standing on one leg	26 (58)	11 (24)	7 (16)	1 (2)	83 (92)	7 (8)	0 (0)	0 (0)
Skipping	41 (92)	2 (4)	1 (2)	1 (2)	87 (97)	3 (3)	0 (0)	0 (0)
Left-right discrimination and hand-eye-foot preference	29 (65)	16 (35)	0 (0)	0 (0)	69 (77)	21 (23)	0 (0)	0 (0)
Behaviour	39 (87)	6 (13)	0 (0)	0 (0)	89 (99)	1 (1)	0 (0)	0 (0)

TABLE A.7.2

Performance on individual items of Quick Neurological Screening Test by birthweight grouping: index children (1000-1499g) and matched classroom peers

	Index (1000-1499g) (N=255)				*Comparison B (N=500)*			
	Normal	*Suspicious*	*Abnormal*	*Unable to complete*	*Normal*	*Suspicious*	*Abnormal*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	231 (90)	22 (9)	2 (1)	0 (0)	487 (97)	13 (3)	0 (0)	0 (0)
Figure recognition	161 (63)	84 (33)	10 (4)	0 (0)	367 (73)	130 (26)	3 (1)	0 (0)
Palm form	158 (62)	78 (31)	18 (7)	1 (0.4)	357 (71)	132 (27)	10 (2)	1 (0.2)
Eye tracking	205 (80)	35 (14)	15 (6)	0 (0)	471 (94)	25 (5)	4 (1)	0 (0)
Sound patterns	61 (24)	191 (75)	2 (1)	1 (0.4)	235 (47)	261 (52)	4 (1)	0 (0)
Finger to nose	167 (66)	52 (20)	35 (14)	1 (0.4)	399 (80)	70 (14)	31 (6)	0 (0)
Thumb and finger circle	163 (64)	79 (31)	11 (5)	2 (1)	360 (72)	128 (26)	12 (2)	0 (0)
Double simultaneous stimulation of hand and cheek	46 (18)	164 (64)	45 (18)	0 (0)	140 (28)	303 (61)	57 (11)	0 (0)
Rapidly reversing repetitive hand movements	91 (36)	127 (50)	36 (14)	1 (0.4)	236 (47)	223 (45)	40 (8)	1 (0.2)
Arm and leg extensions	40 (16)	196 (77)	19 (7)	0 (0)	178 (35)	313 (63)	9 (2)	0 (0)
Tandem walk	173 (68)	71 (28)	8 (3)	3 (1)	437 (87)	61 (12)	2 (1)	0 (0)
Standing on one leg	205 (80)	32 (13)	16 (6)	2 (1)	471 (94)	23 (5)	6 (1)	0 (0)
Skipping	228 (89)	21 (8)	4 (2)	2 (1)	482 (97)	17 (3)	1 (0.2)	0 (0)
Left-right discrimination and hand-eye-foot preference	179 (70)	75 (30)	0 (0)	1 (0.4)	376 (75)	124 (25)	0 (0)	0 (0)
Behaviour	236 (93)	14 (5)	4 (2)	1 (0.4)	488 (97)	8 (2)	4 (1)	0 (0)

Table A.7.3

Performance on individual items of Quick Neurological Screening Test by birthweight grouping: index children (<1000g) and matched classroom peers - categorised as normal, suspicious, abnormal and unable to complete

	<1000g	*Comparison A*	*<1000g*	*Comparison A*	*<1000g*	*Comparison A*	*<1000g*	*Comparison A*
	Normal	*Normal*	*Suspicious*	*Suspicious*	*Abnormal*	*Abnormal*	*Unable to complete*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	35 (78)	89 (99)	9 (20)	1 (1)	1 (2)	0 (0)	0 (0)	0 (0)
Figure recognition	20 (44.5)	80 (89)	20 (44.5)	10 (11)	5 (11)	0 (0)	0 (0)	0 (0)
Palm form	24 (54)	74 (82)	18 (40)	14 (16)	2 (4)	1 (1)	1 (2)	1 (1)
Eye tracking	32 (71)	87 (97)	8 (18)	2 (2)	5 (11)	1 (1)	0 (0)	0 (0)
Sound patterns	10 (23)	40 (45)	33 (73)	48 (53)	1 (2)	2 (2)	1 (2)	0 (0)
Finger to nose	23 (51)	74 (82)	12 (27)	12 (13)	10 (22)	4 (5)	0 (0)	0 (0)
Thumb and finger circle	24 (53)	69 (77)	15 (34)	21 (23)	5 (11)	0 (0)	1 (2)	0 (0)
Double simultaneous stimulation of hand and cheek	7 (16)	24 (27)	33 (73)	57 (63)	5 (11)	9 (10)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	7 (16)	47 (52)	26 (58)	35 (39)	11 (24)	7 (8)	1 (2)	1 (1)
Arm and leg extensions	3 (7)	44 (49)	33 (73)	46 (51)	9 (20)	0 (0)	0 (0)	0 (0)
Tandem walk	29 (65)	81 (90)	10 (22)	9 (10)	5 (11)	0 (0)	1 (2)	0 (0)
Standing on one leg	26 (58)	83 (92)	11 (24)	7 (8)	7 (16)	0 (0)	1 (2)	0 (0)
Skipping	41 (92)	87 (97)	2 (4)	3 (3)	1 (2)	0 (0)	1 (2)	0 (0)
Left-right discrimination and hand-eye-foot preference	29 (65)	69 (77)	16 (35)	21 (23)	0 (0)	0 (0)	0 (0)	0 (0)
Behaviour	39 (87)	89 (99)	6 (13)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)

Table A.7.4

Performance on individual items of Quick Neurological Screening Test by birthweight grouping: index children (1000-1499g) and matched classroom peers - categorised as normal, suspicious, abnormal and unable to complete

	1000-1499g	*Comparison B*	*1000-1499g*	*Comparison B*	*1000-1499g*	*Comparison B*	*1000-1499g*	*Comparison B*
	Normal	*Normal*	*Suspicious*	*Suspicious*	*Abnormal*	*Abnormal*	*Unable to complete*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	231 (90)	487 (97)	22 (9)	13 (3)	2 (1)	0 (0)	0 (0)	0 (0)
Figure recognition	161 (63)	367 (73)	84 (33)	130 (26)	10 (4)	3 (1)	0 (0)	0 (0)
Palm form	158 (62)	357 (71)	78 (31)	132 (27)	18 (7)	10 (2)	1 (0.4)	1 (0.2)
Eye tracking	205 (80)	471 (94)	35 (14)	25 (5)	15 (6)	4 (1)	0 (0)	0 (0)
Sound patterns	61 (24)	235 (47)	191 (75)	261 (52)	2 (1)	4 (1)	1 (0.4)	0 (0)
Finger to nose	167 (66)	399 (80)	52 (20)	70 (14)	35 (14)	31 (6)	1 (0.4)	0 (0)
Thumb and finger circle	163 (64)	360 (72)	79 (31)	128 (26)	11 (5)	12 (2)	2 (1)	0 (0)
Double simultaneous stimulation of hand and cheek	46 (18)	140 (28)	164 (64)	303 (61)	45 (18)	57 (11)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	91 (36)	236 (47)	127 (50)	223 (45)	36 (14)	40 (8)	1 (0.4)	1 (0.2)
Arm and leg extensions	40 (16)	178 (35)	196 (77)	313 (63)	19 (7)	9 (2)	0 (0)	0 (0)
Tandem walk	173 (68)	437 (87)	71 (28)	61 (12)	8 (3)	2 (1)	3 (1)	0 (0)
Standing on one leg	205 (80)	471 (94)	32 (13)	23 (5)	16 (6)	6 (1)	2 (1)	0 (0)
Skipping	228 (89)	482 (97)	21 (8)	17 (3)	4 (2)	1 (0.2)	2 (1)	0 (0)
Left-right discrimination and hand-eye-foot preference	179 (70)	376 (75)	75 (30)	124 (25)	0 (0)	0 (0)	1 (0.4)	0 (0)
Behaviour	236 (93)	488 (97)	14 (5)	8 (2)	4 (2)	4 (1)	1 (0.4)	0 (0)

Table A.7.5
Performance on individual items of Quick Neurological Screening Test by birthweight grouping: index children (<1000) and index children (1000-1499g) - categorised as normal, suspicious, abnormal and unable to complete

	<1000g	*1000-1499g*	*<1000g*	*1000-1499g*	*<1000g*	*1000-1499g*	*<1000g*	*1000-1499g*
	Normal	*Normal*	*Suspicious*	*Suspicious*	*Abnormal*	*Abnormal*	*Unable to complete*	*Unable to complete*
QNST	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Hand skill	35 (78)	231 (90)	9 (20)	22 (9)	1 (2)	2 (1)	0 (0)	0 (0)
Figure recognition	20 (44.5)	161 (63)	20 (44.5)	84 (33)	5 (11)	10 (4)	0 (0)	0 (0)
Palm form	24 (54)	158 (62)	18 (40)	78 (31)	2 (4)	18 (7)	1 (2)	1 (0.4)
Eye tracking	32 (71)	205 (80)	8 (18)	35 (14)	5 (11)	15 (6)	0 (0)	0 (0)
Sound patterns	10 (23)	61 (24)	33 (73)	191 (75)	1 (2)	2 (1)	1 (2)	1 (0.4)
Finger to nose	23 (51)	167 (66)	12 (27)	52 (20)	10 (22)	35 (14)	0 (0)	1 (0.4)
Thumb and finger circle	24 (53)	163 (64)	15 (34)	79 (31)	5 (11)	11 (5)	1 (2)	2 (1)
Double simultaneous stimulation of hand and cheek	7 (16)	46 (18)	33 (73)	164 (64)	5 (11)	45 (18)	0 (0)	0 (0)
Rapidly reversing repetitive hand movements	7 (16)	91 (36)	26 (58)	127 (50)	11 (24)	36 (14)	1 (2)	1 (0.4)
Arm and leg extensions	3 (7)	40 (16)	33 (73)	196 (77)	9 (20)	19 (7)	0 (0)	0 (0)
Tandem walk	29 (65)	173 (68)	10 (22)	71 (28)	5 (11)	8 (3)	1 (2)	3 (1)
Standing on one leg	26 (58)	205 (80)	11 (24)	32 (13)	7 (16)	16 (6)	1 (2)	2 (1)
Skipping	41 (92)	228 (89)	2 (4)	21 (8)	1 (2)	4 (2)	1 (2)	2 (1)
Left-right discrimination and hand-eye-foot preference	29 (65)	179 (70)	16 (35)	75 (30)	0 (0)	0 (0)	0 (0)	1 (0.4)
Behaviour	39 (87)	236 (93)	6 (13)	14 (5)	0 (0)	4 (2)	0 (0)	1 (0.4)

Appendix 8

Scottish Low Birthweight Study – Investigation of Relationship of Motor Competence to Intellectual Functioning

Section 1 Verbal Scales of the British Ability Scales

A.8.1 Detailed description of two-way ANOVAs for verbal scales of BAS by motor competence and level of intellectual functioning (index group)

A.8.1.1 Similarities (British Ability Scales)

TABLE A.8.1.1

Differences in mean Similarities scores of index children by motor competence and level of intellectual functioning: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		38.0	42.0	50.7	51.2
> 1 SD below mean	>10th percentile	(1)		0.234	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.234		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.980
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.980	

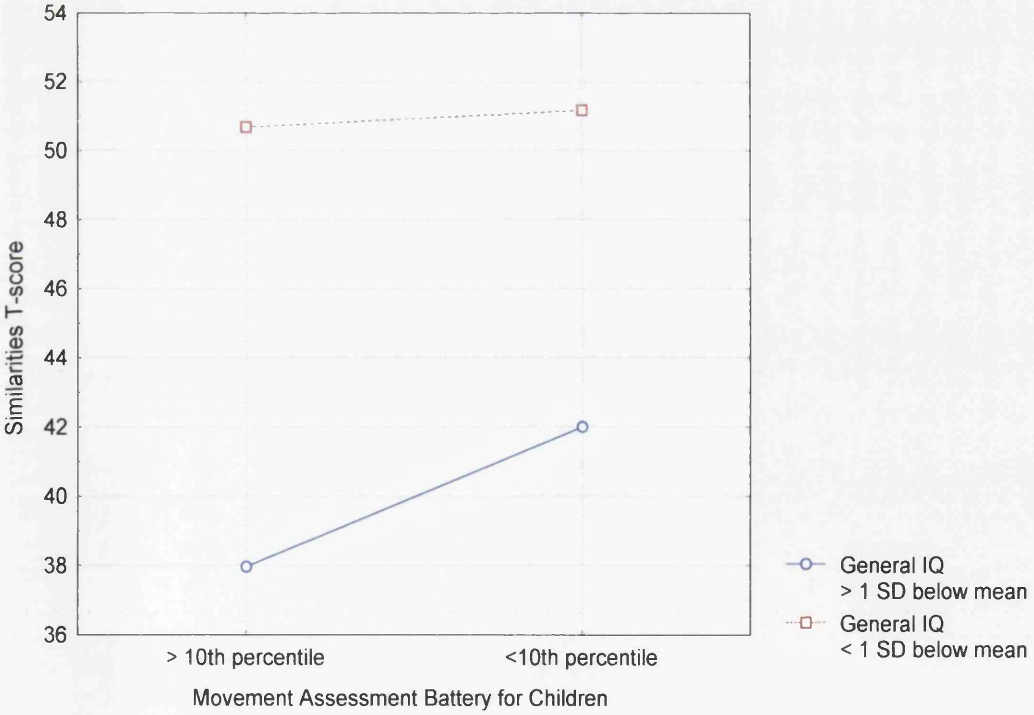

Figure A.8.1.1 *Plot of means (two way interaction) for Similarities by motor competence and IQ status (index group)*

A.8.1.2 Recall of Digits (British Ability Scales)

TABLE A.8.1.2

Differences in mean Recall of Digits scores of index children by motor competence and level of intellectual functioning: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		44.5	42.2	49.4	50.7
> 1 SD below mean	>10th percentile	(1)		0.796	0.090	0.034
> 1 SD below mean	<10th percentile	(2)	0.796		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.090	0.000		0.805
< 1 SD below mean	<10th percentile	(4)	0.034	0.000	0.805	

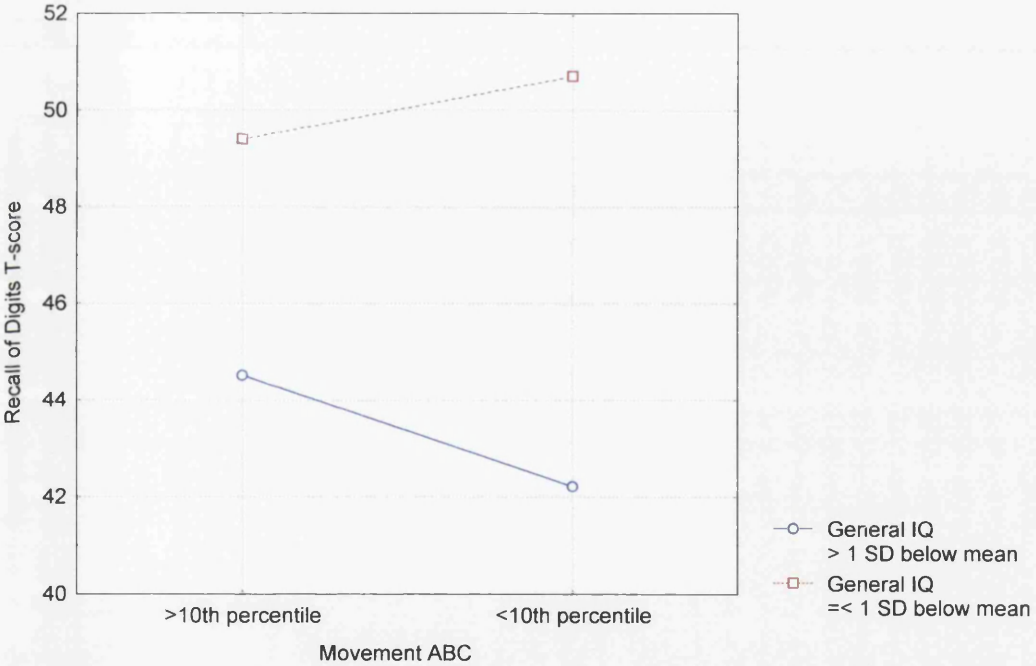

Figure A.8.1.2 *Plot of means (two way interaction) for Recall of Digits by motor competence and IQ status (index group)*

A.8.1.3 Speed of Information Processing (British Ability Scales)

TABLE A.8.1.3

Differences in mean Speed of Information Processing scores of index children by motor competence and level of intellectual functioning: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		40.2	41.8	50.7	46.1
> 1 SD below mean	>10th percentile	(1)		0.919	0.000	0.033
> 1 SD below mean	<10th percentile	(2)	0.919		0.000	0.097
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.006
< 1 SD below mean	<10th percentile	(4)	0.033	0.097	0.006	

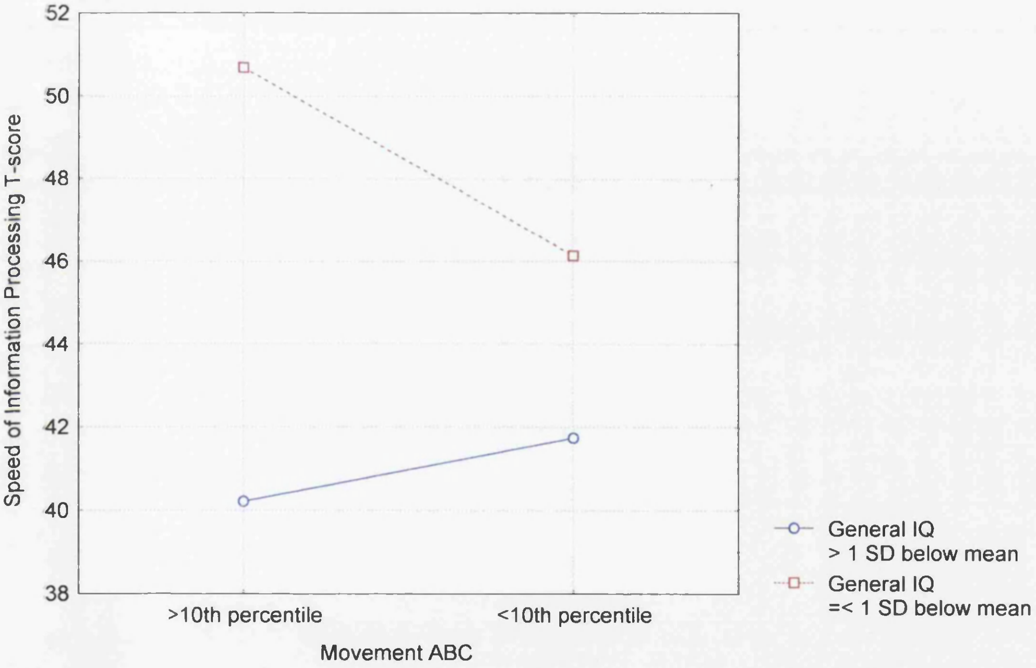

Figure A.8.1.3 *Plot of means (two way interaction) for Speed of Information Processing by motor competence and IQ status (index group)*

A.8.1.4 Word Definitions (British Ability Scales)

Table A.8.1.4

Differences in mean Word Definitions scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		34.0	31.6	41.9	41.6
> 1 SD below mean	>10th percentile	(1)		0.677	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.677		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.997
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.997	

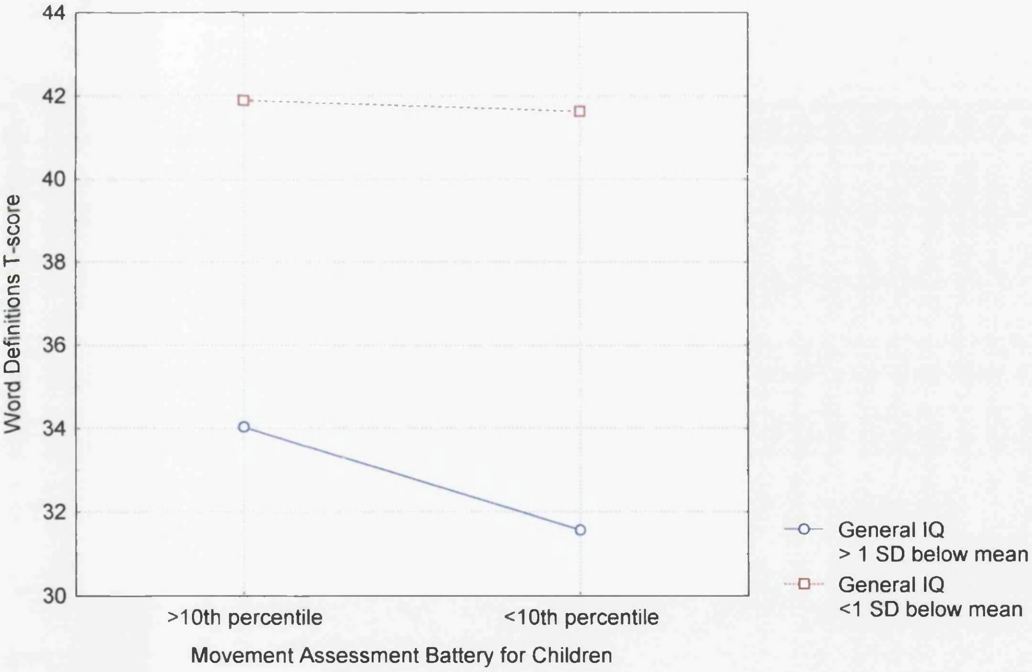

Figure A.8.1.4 *Plot of means (two way interaction) for Word Definitions by motor competence and IQ status (index group)*

A.8.1.5 Composite Verbal IQ (British Ability Scales)

Table A.8.1.5

Differences in mean Composite Verbal IQ scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		77.0	77.4	96.1	94.8
> 1 SD below mean	>10th percentile	(1)		0.999	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.999		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.872
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.872	

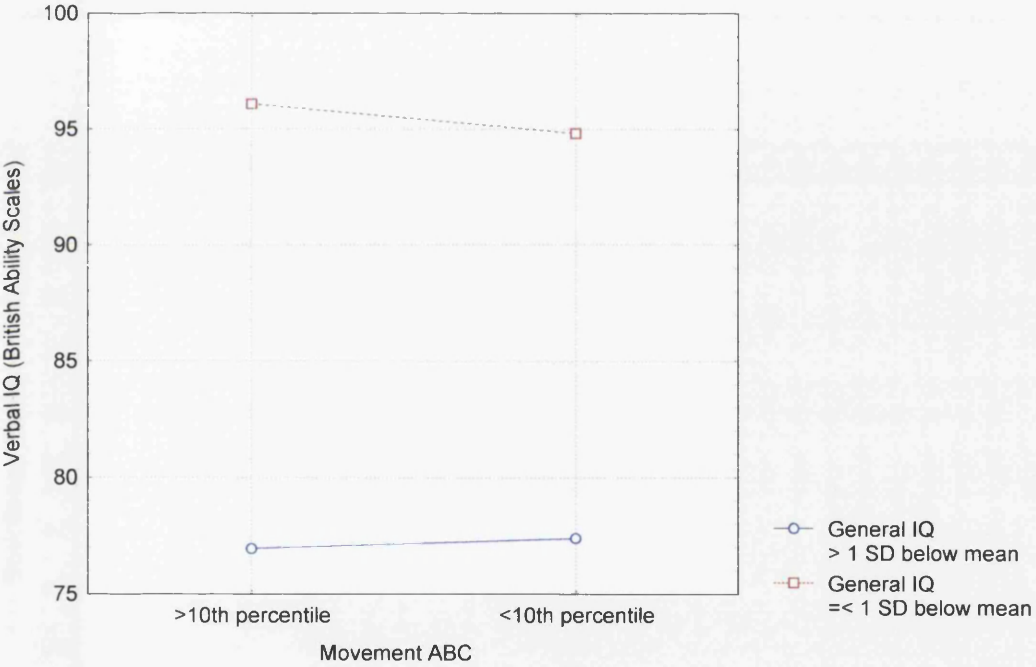

Figure A.8.1.5 *Plot of means (two way interaction) for Verbal IQ (BAS) by motor competence and IQ status (index group)*

Section 2 Visual Scales of the British Ability Scales

A.8.2 Detailed description of two-way ANOVAs for visual scales of BAS by motor competence and level of intellectual functioning (index group)

A.8.2.1 Block Design (British Ability Scales)

TABLE A.8.2.1

Differences in mean Block Design scores of index children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		39.2	35.8	51.6	47.7
> 1 SD below mean	>10th percentile	(1)		0.443	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.443		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.020
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.020	

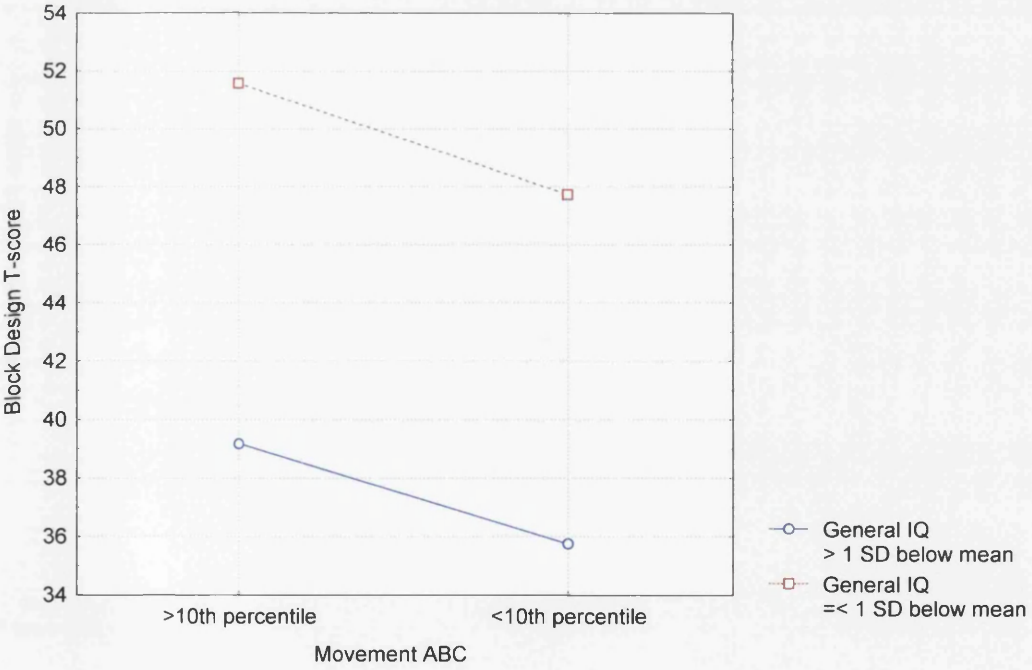

Figure A.8.2.1 *Plot of means (two way interaction) for Block Design by motor competence and IQ status (index group)*

A.8.2.2 Recall of Designs (British Ability Scales)

TABLE A.8.2.2

Differences in mean Recall of Designs scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		44.8	40.8	54.8	50.4
> 1 SD below mean	>10th percentile	(1)		0.280	0.000	0.029
> 1 SD below mean	<10th percentile	(2)	0.280		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.004
< 1 SD below mean	<10th percentile	(4)	0.029	0.000	0.004	

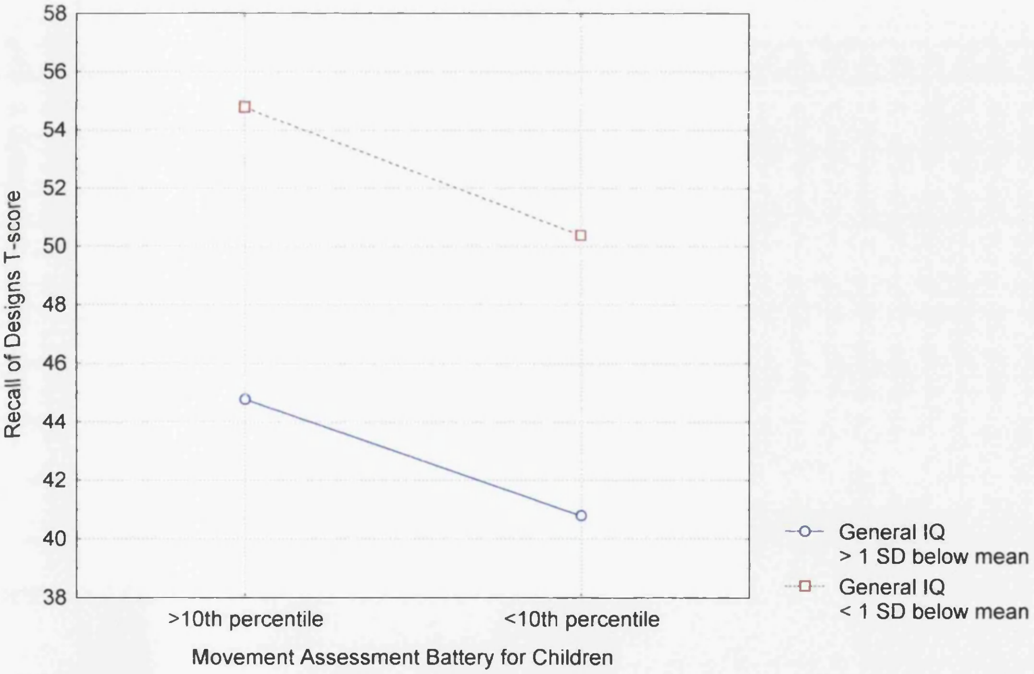

Figure A.8.2.2 *Plot of means (two way interaction) for Recall of Designs by motor competence and IQ status (index group)*

A.8.2.3 Matrices (British Ability Scales)

TABLE A.8.2.3

Differences in mean Matrices scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		36.9	36.4	48.8	48.8
> 1 SD below mean	>10th percentile	(1)		0.990	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.990		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.999
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.999	

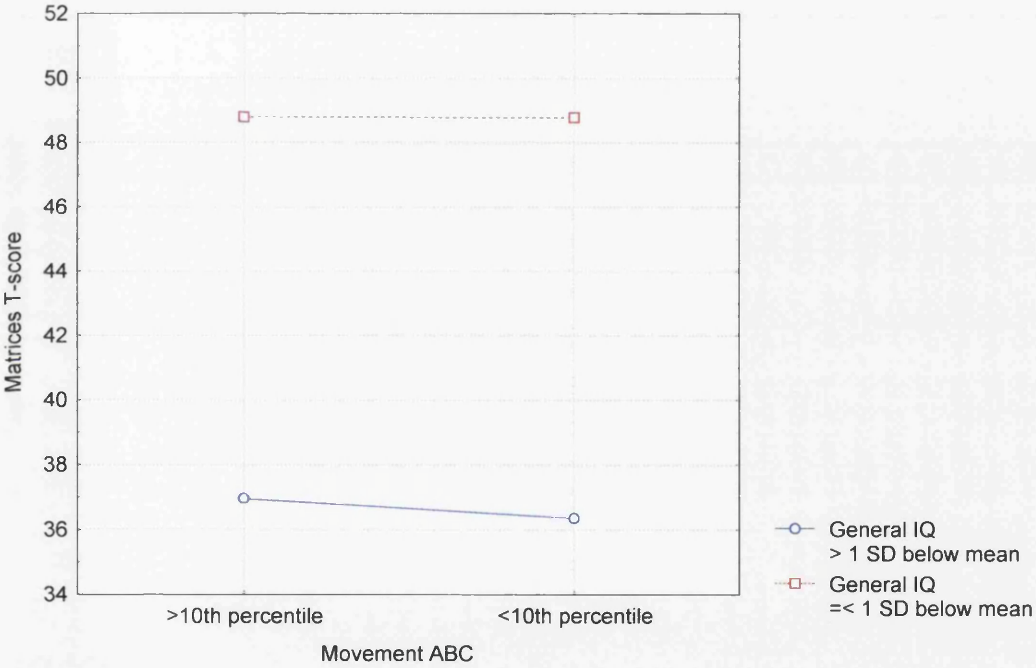

Figure A.8.2.3 *Plot of means (two way interaction) for Matrices by motor competence and IQ status (index group)*

A.8.2.4 Composite Visual IQ (British Ability Scales)

Table A.8.2.4

Differences in mean Composite Visual IQ scores of index children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		79.4	73.7	103.7	97.8
> 1 SD below mean	>10th percentile	(1)		0.276	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.276		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.008
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.008	

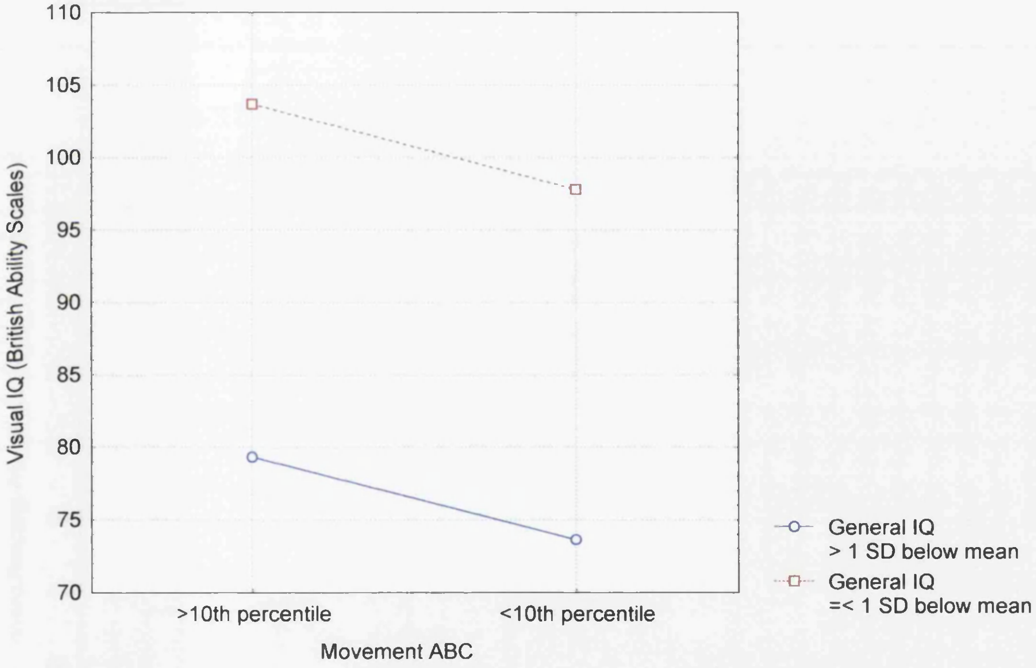

Figure A.8.2.4 *Plot of means (two way interaction) for Visual IQ (BAS) by motor competence and IQ status (index group)*

Section 3 Scholastic Attainment Scales of the British Ability Scales

A.8.3 Detailed description of two-way ANOVAs for attainment scales of BAS by motor competence and level of intellectual functioning (index group)

A.8.3.1 Word Reading (British Ability Scales)

TABLE A.8.3.1

Differences in mean Word Reading scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		40.2	42.5	52.4	51.7
> 1 SD below mean	>10th percentile	(1)		0.822	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.822		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.975
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.975	

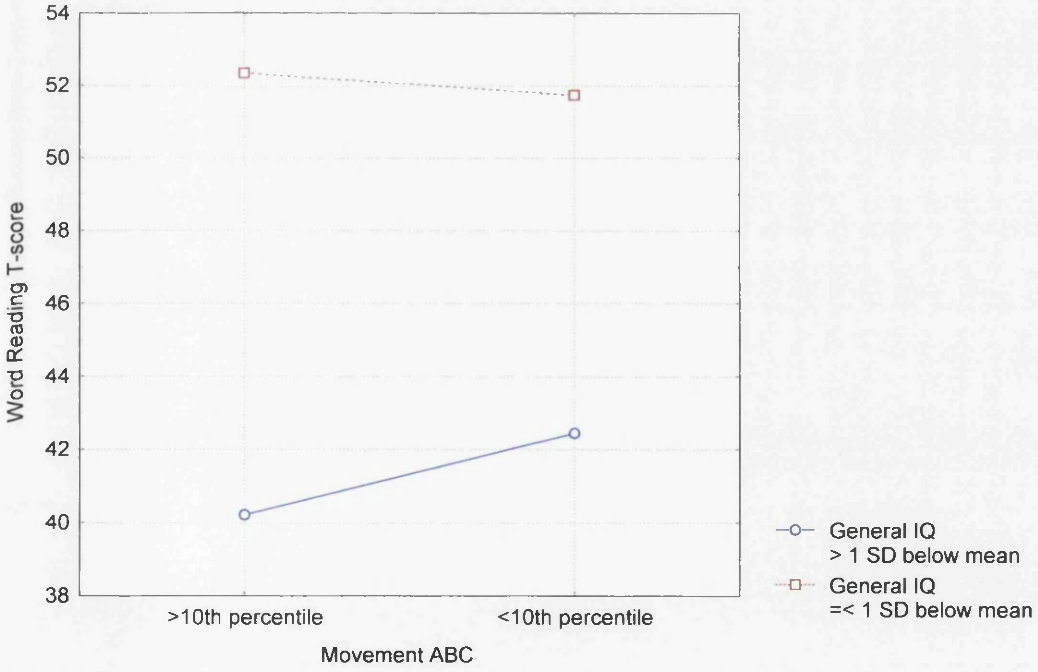

Figure A.8.3.1 *Plot of means (two way interaction) for Word Reading by motor competence and IQ status (index group)*

A.8.3.2 Number Skills (British Ability Scales)

TABLE A.8.3.2

Differences in mean Basic Number Skills scores of index children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		37.3	37.6	47.0	45.4
> 1 SD below mean	>10th percentile	(1)		0.999	0.000	0.001
> 1 SD below mean	<10th percentile	(2)	0.999		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.617
< 1 SD below mean	<10th percentile	(4)	0.001	0.000	0.617	

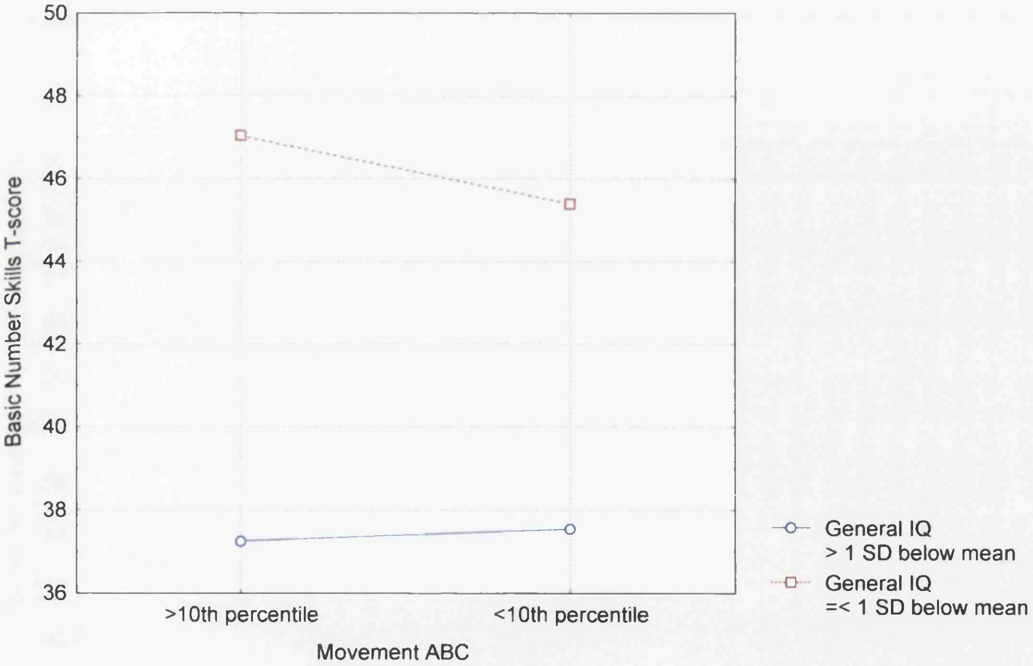

Figure A.8.3.2 *Plot of means (two way interaction) for Basic Number Skills by motor competence and IQ status (index group)*

Homogeneity of variance

Levene's test for homogeneity of variance was performed for all the above analyses. No significant results were observed with the exception of Word Definitions. As there were no significant differences in the comparisons of interest on this scale, the significant Levene score is of no consequence.

Section 4 Verbal Scales of the British Ability Scales

A.8.4 Detailed description of two-way ANOVAs for verbal scales of BAS by motor competence and level of intellectual functioning (comparison group)

A.8.4.1 Similarities (British Ability Scales)

TABLE A.8.4.1

Differences in mean Similarities scores of comparison children by motor competence and level of intellectual functioning: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		37.3	42.2	52.2	52.9
> 1 SD below mean	>10th percentile	(1)		0.291	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.291		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.951
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.951	

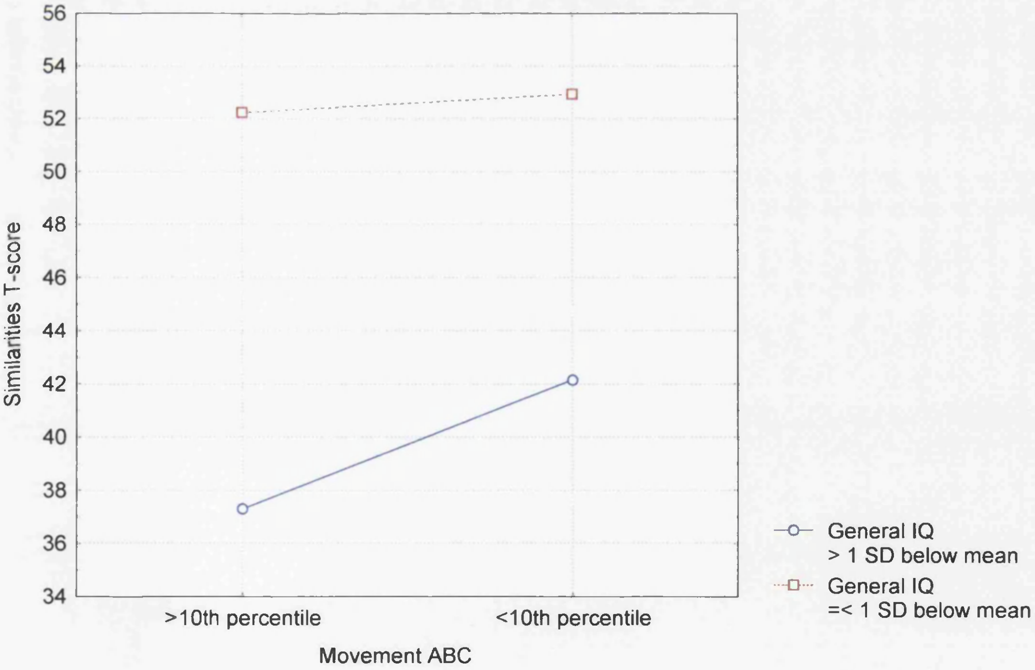

Figure A.8.4.1 *Plot of means (two way interaction) for Similarities by motor competence and IQ status (comparison group)*

A.8.4.2 Recall of Digits (British Ability Scales)

TABLE A.8.4.2

Differences in mean Recall of Digits scores of comparison children by motor competence and level of intellectual functioning: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		42.2	43.2	49.9	47.6
> 1 SD below mean	>10th percentile	(1)		0.986	0.000	0.016
> 1 SD below mean	<10th percentile	(2)	0.986		0.031	0.374
< 1 SD below mean	>10th percentile	(3)	0.000	0.031		0.273
< 1 SD below mean	<10th percentile	(4)	0.016	0.374	0.273	

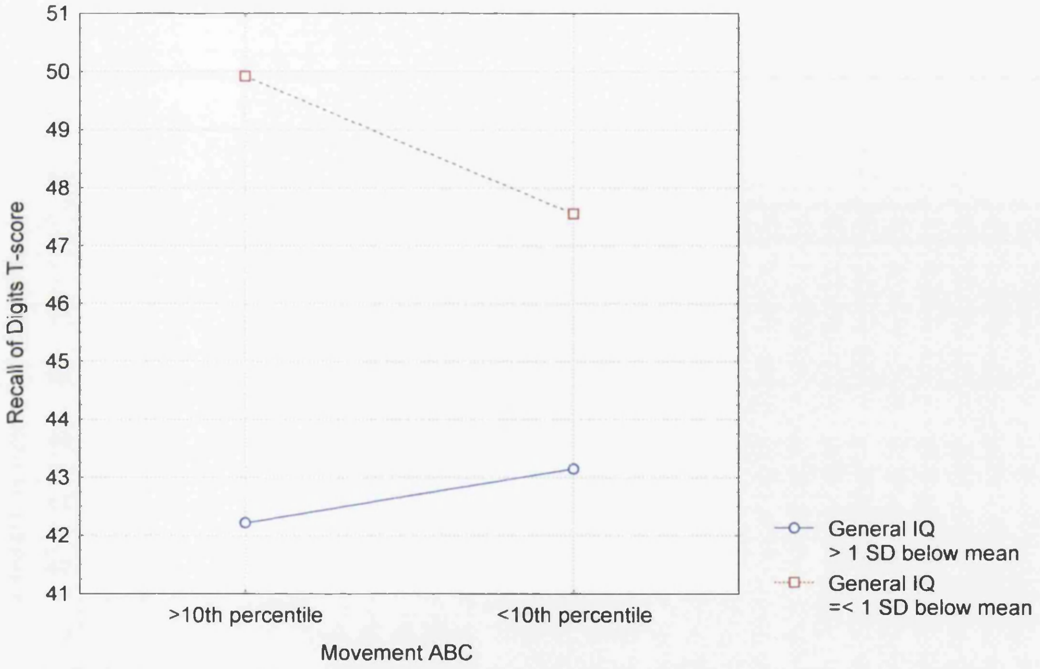

Figure A.8.4.2 *Plot of means (two way interaction) for Recall of Digits by motor competence and IQ status (comparison group)*

A.8.4.3 Speed of Information Processing (British Ability Scales)

TABLE A.8.4.3

Differences in mean Speed of Information Processing scores of comparison children by motor competence and level of intellectual functioning: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		42.9	40.7	53.5	51.2
> 1 SD below mean	>10th percentile	(1)		0.886	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.886		0.000	0.002
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.369
< 1 SD below mean	<10th percentile	(4)	0.000	0.002	0.369	

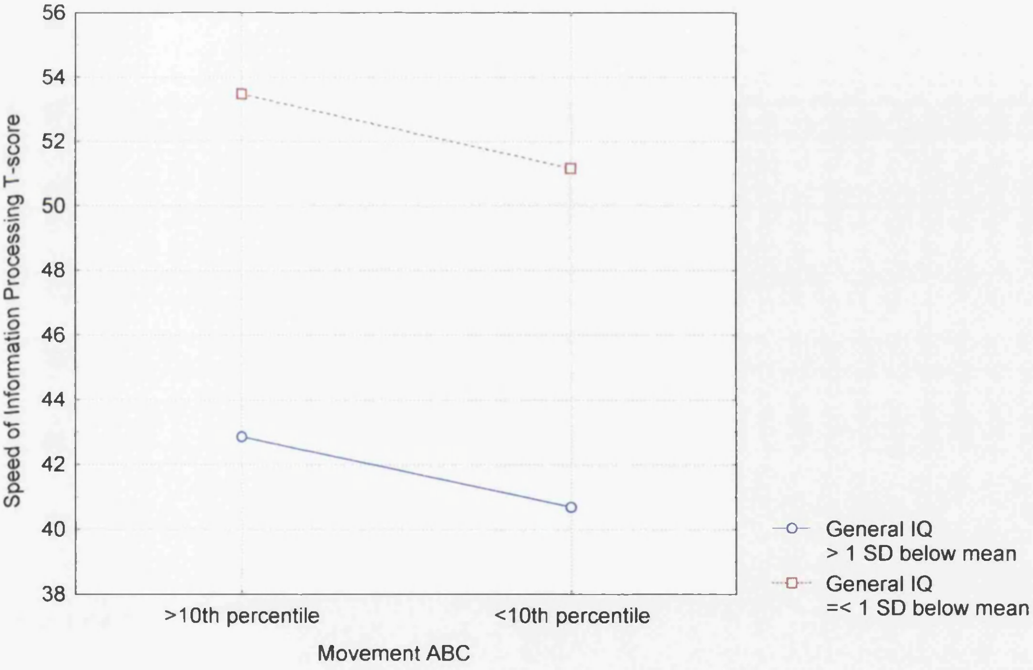

Figure A.8.4.3 Plot of means (two way interaction) for Speed of Information Processing by motor competence and IQ status (comparison group)

A.8.4.4 Word Definitions (British Ability Scales)

Table A.8.4.4

Differences in mean Word Definitions scores of comparison children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		33.1	34.9	44.3	42.6
> 1 SD below mean	>10th percentile	(1)		0.917	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.917		0.001	0.027
< 1 SD below mean	>10th percentile	(3)	0.000	0.001		0.572
< 1 SD below mean	<10th percentile	(4)	0.000	0.027	0.572	

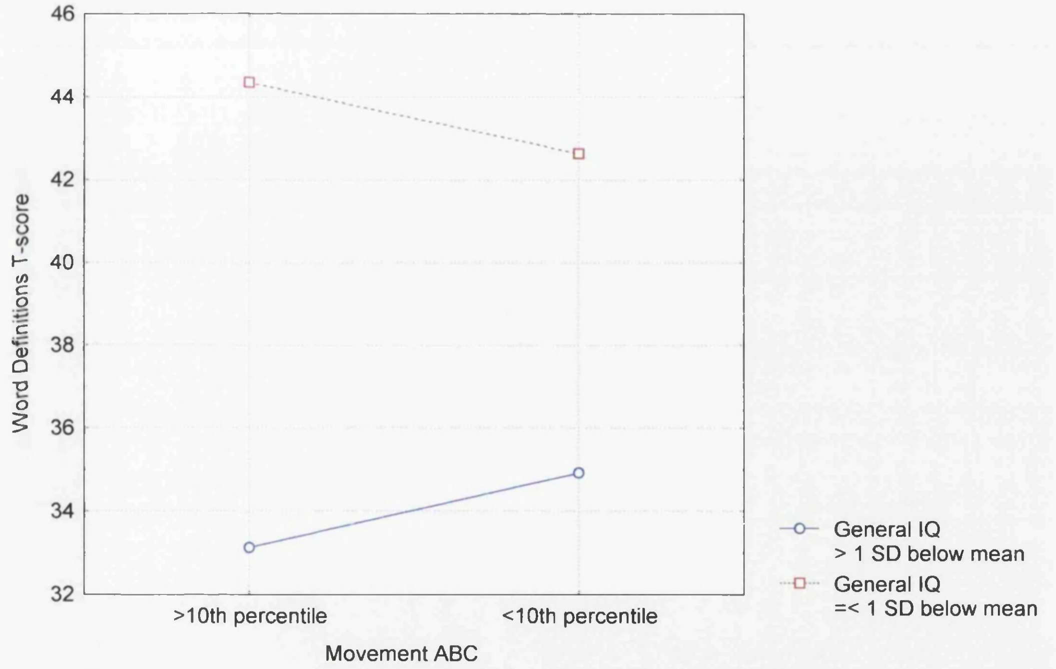

Figure A.8.4.4 *Plot of means (two way interaction) for Word Definitions by motor competence and IQ status (comparison group)*

A.8.4.5 Composite Verbal IQ (British Ability Scales)

Table A.8.4.5

Differences in mean Composite Verbal IQ scores of comparison children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		76.3	79.2	100.0	97.0
> 1 SD below mean	>10th percentile	(1)		0.859	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.859		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.301
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.301	

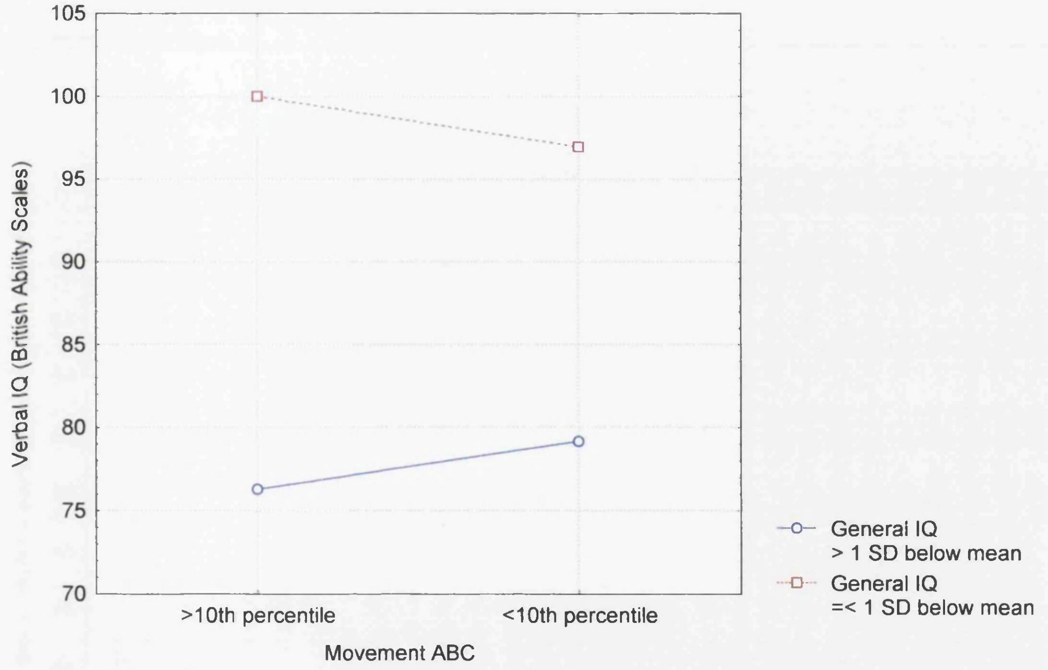

Figure A.8.4.5 Plot of means (two way interaction) for Verbal IQ by motor competence and IQ status (comparison group)

Section 5 Visual Scales of the British Ability Scales

A.8.5 Detailed description of two-way ANOVAs for visual scales of BAS by motor competence and level of intellectual functioning (comparison group)

A.8.5.1 Block Design (British Ability Scales)

TABLE A.8.5.1

Differences in mean Block Design scores of comparison children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		39.7	42.8	55.2	53.7
> 1 SD below mean	>10th percentile	(1)		0.652	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.652		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.685
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.685	

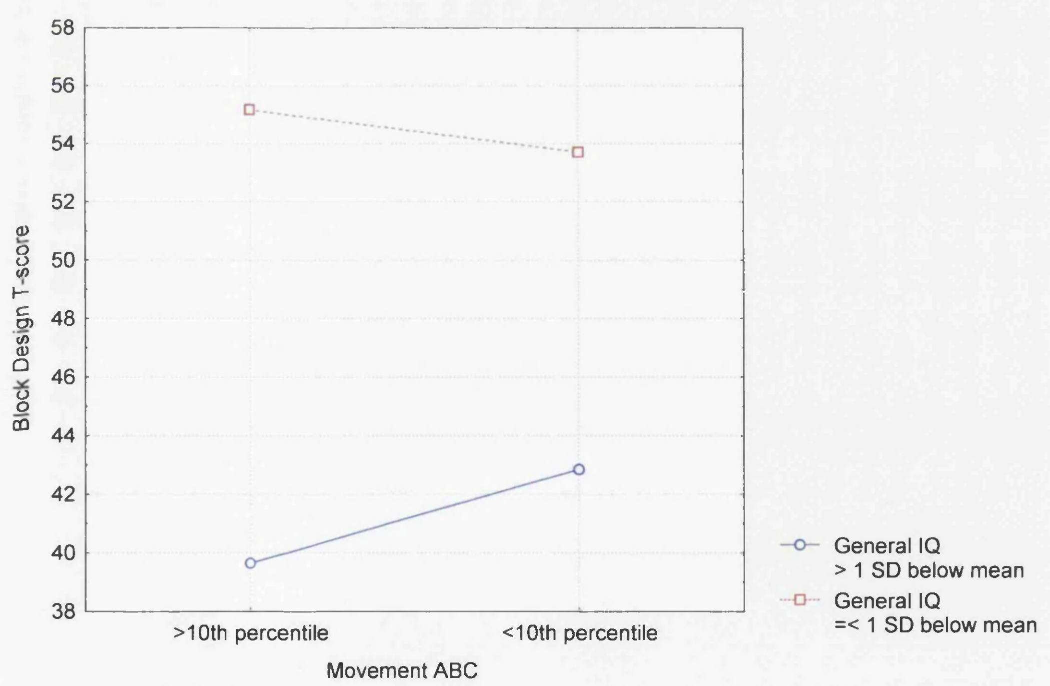

Figure A.8.5.1 *Plot of means (two way interaction) for Block Design by motor competence and IQ status (comparison group)*

A.8.5.2 Recall of Designs (British Ability Scales)

TABLE A.8.5.2

Differences in mean Recall of Designs scores of comparison children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		45.5	43.2	56.8	55.1
> 1 SD below mean	>10th percentile	(1)		0.813	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.813		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.520
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.520	

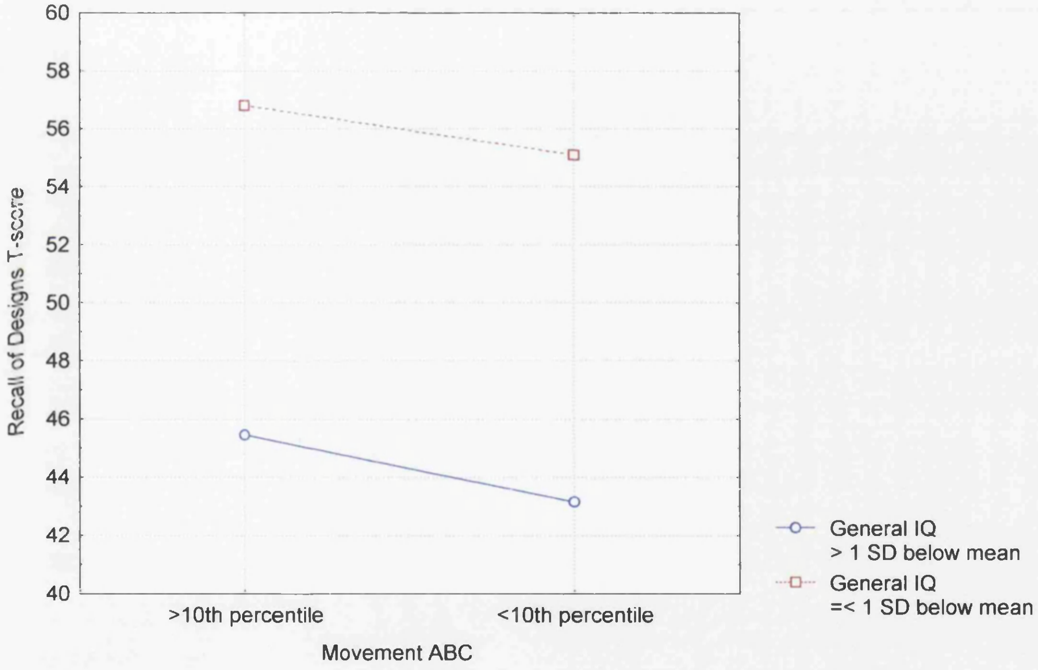

Figure A.8.5.2 *Plot of means (two way interaction) for Recall of Designs by motor competence and IQ status (comparison group)*

A.8.5.3 Matrices (British Ability Scales)

TABLE A.8.5.3

Differences in mean Matrices scores of comparison children by IQ status and motor competence: two–way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		40.6	39.7	51.1	50.3
> 1 SD below mean	>10th percentile	(1)		0.985	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.985		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.933
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.933	

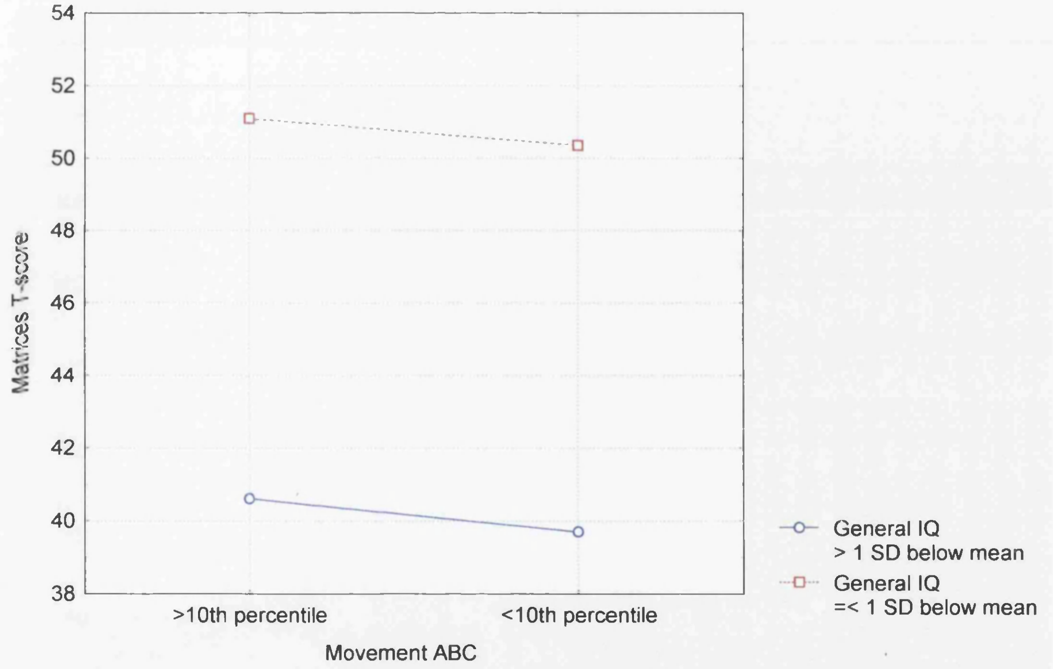

Figure A.8.5.3 *Plot of means (two way interaction) for Matrices by motor competence and IQ status (comparison group)*

A.8.5.4 Composite Visual IQ (British Ability Scales)

Table A.8.5.4

Differences in mean Composite Visual IQ scores of comparison children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		82.8	82.7	109.3	106.5
> 1 SD below mean	>10th percentile	(1)		1.000	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	1.000		0.000	0.000
< 1 SD below mean	>10th percentile	(3)	0.000	0.000		0.487
< 1 SD below mean	<10th percentile	(4)	0.000	0.000	0.487	

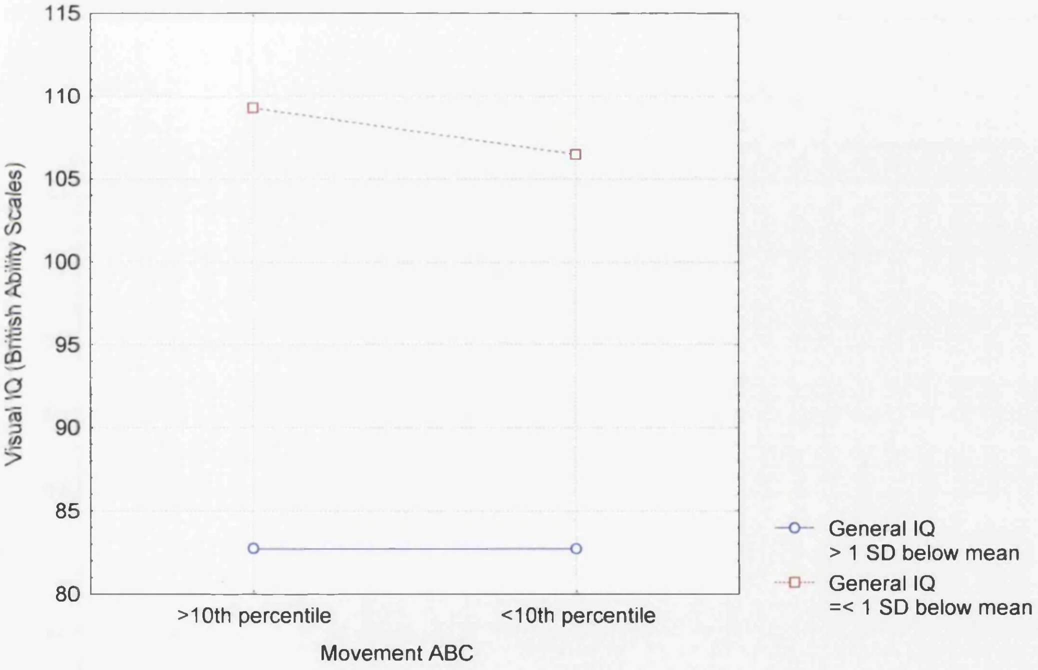

Figure A.8.5.4 *Plot of means (two way interaction) for Visual IQ (BAS) by motor competence and IQ status (comparison group)*

Section 6 Scholastic Attainment Scales of the British Ability Scales

A.8.6 Detailed description of two-way ANOVAs for attainment scales of BAS by motor competence and level of intellectual functioning (index group)

A.8.6.1 Word Reading (British Ability Scales)

TABLE A.8.6.1

Differences in mean Word Reading scores of comparison children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		42.7	44.3	54.0	52.2
> 1 SD below mean	>10th percentile	(1)		0.958	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.958		0.005	0.072
< 1 SD below mean	>10th percentile	(3)	0.000	0.005		0.661
< 1 SD below mean	<10th percentile	(4)	0.000	0.072	0.661	

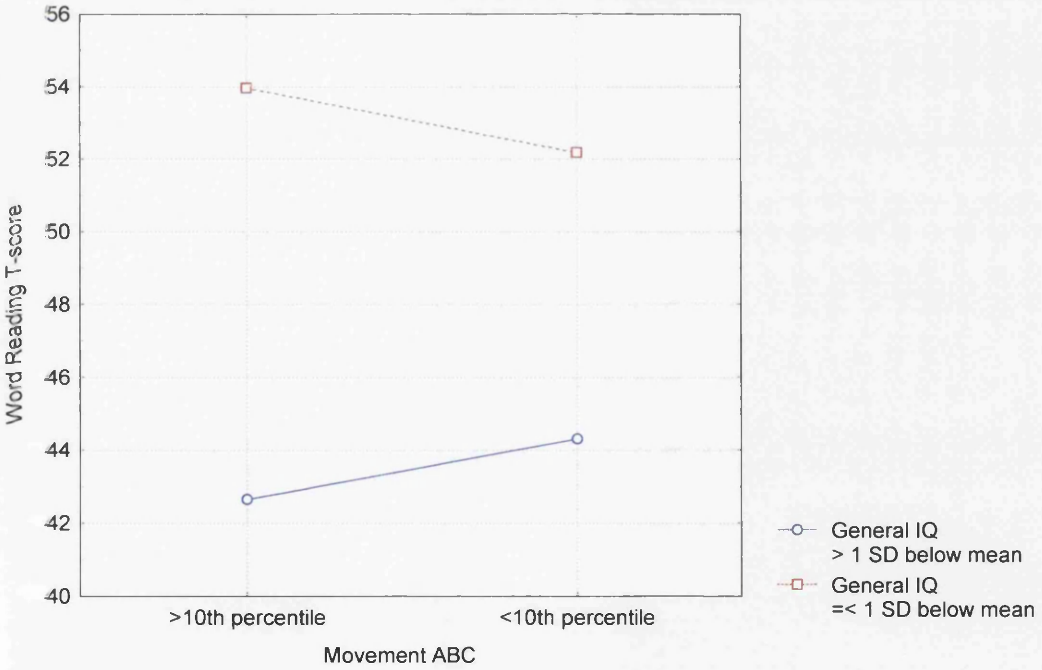

Figure A.8.6.1 *Plot of means (two way interaction) for Word Reading by motor competence and IQ status (comparison group)*

A.8.6.2 Number Skills (British Ability Scales)

TABLE A.8.6.2

Differences in mean Basic Number Skills scores of comparison children by IQ status and motor competence: two-way ANOVA and Tukey HSD post hoc test

			(1)	(2)	(3)	(4)
IQ status	*Motor status*		40.2	41.4	50.0	51.0
> 1 SD below mean	>10th percentile	(1)		0.982	0.000	0.000
> 1 SD below mean	<10th percentile	(2)	0.982		0.008	0.007
< 1 SD below mean	>10th percentile	(3)	0.000	0.008		0.895
< 1 SD below mean	<10th percentile	(4)	0.000	0.007	0.895	

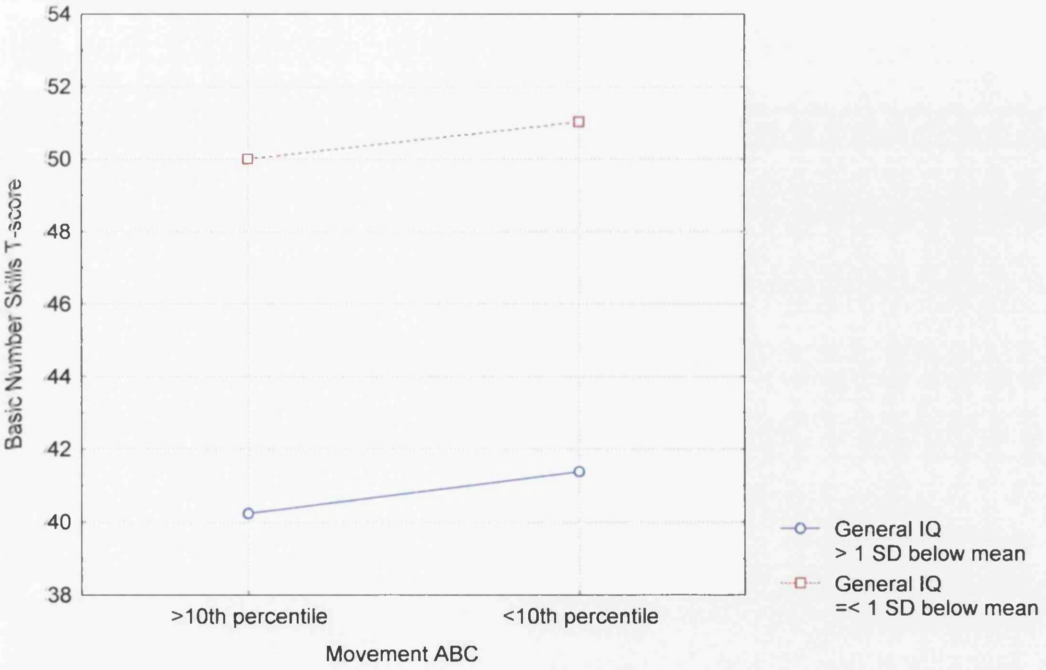

Figure A.8.6.2 *Plot of means (two way interaction) for Basic Number Skills by motor competence and IQ status (comparison group)*

Homogeneity of variance

Levene's test for homogeneity of variance was performed on all the analyses for the comparison group. Significant results were observed for the analyses of Similarities, Word Definitions, Verbal IQ, Visual IQ, Word Reading and Basic Number Skills. It is likely that lack of homogeneity of variance on so many of the analyses for the comparison group came about as a result of the relatively small number of children in this group performing below the 10th percentile on the Movement ABC – especially so for the group that were also of below average intellectual ability.

The small numbers may also account for the lack of significance in the results for the comparison group. That is, on the scales of visual processing the direction of the difference was always in the predicted direction with the single exception of Block Design for those children with IQs more than 1 SD below the mean. Although visual processing scale scores were always lower for those children performing below the 10th percentile on the Movement ABC, with the aforementioned exception, none of these differences was significant.

Appendix 9

A.9.1 The use of concurrent norms in relation to the proportion of index children functioning below the 10th percentile in reading and number

Tables A.9.1 and A.9.2 below present the proportion of index and comparison children performing below the 10th percentile on measures of scholastic attainment for the test norms and for the comparison group respectively.

Tables A.9.3 and A.9.4 presents a break down by birthweight groupings of the proportion of index and comparison children performing below the 10th percentile on reading and number for the test norms and for the comparison group respectively.

TABLE A.9.1

Mean scores and numbers of children functioning below 10th percentile (for the test norms) on school attainment tasks(British Ability Scales) - index children and comparison children

	VLBW Group		*Comparison Group*	
Word reading	49.6	(SD 11.2)	52.7	(SD 10.9)*
N below 10th percentile	44	(14.7%)	36	(6.1%)**
Number skills	44.3	(SD 10.1)	49.1	(SD 10.0)*
N below 10th percentile	62	(20.7%)	42	(7.1%)***

*$p<0.0001$; **χ^2 $p<0.001$; ***χ^2 $p<0.0001$

TABLE A.9.2

Mean scores and numbers of children functioning below 10th percentile (for the comparison group) on school attainment tasks (British Ability Scales) – index children and comparison children

	VLBW Group		*Comparison Group*	
Word reading	49.6	(SD 11.2)	52.7	(SD 10.9)*
N below 10th percentile	62	(20.7%)	67	(11.4%)**
Number skills	44.3	(SD 10.1)	49.1	(SD 10.0)*
N below 10th percentile	75	(25.0%)	63	(10.7%)***

*$p<0.0001$; **χ^2 $p<0.005$; ***χ^2 $p<0.0001$

TABLE A.9.3

Mean scores and numbers of children functioning below 10th percentile (for the test norms) on school attainment tasks(British Ability Scales) by birthweight grouping - index children and comparison children

	<1000g		*Comparison A*		*1000g–1499g*		*Comparison B*		*95% CI*
	Mean	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	
Word reading	47.9	(11.2)	53.2	(10.6)**	49.9	(11.2)	52.6	(10.9)*	(-4.4, -1.0)
N below 10th percentile	8	(17.8%)	2	(2.2%)****	36	(14.1%)	34	(6.8%)*****	
Number skills	40.0	(9.1)	48.9	(10.1)***	45.1	(10.1)	49.2	(10.0)***	(-5.6, -2.6)
N below 10th percentile	17	(37.8%)	9	(10.0%)****	45	(17.6%)	33	(6.6%)******	

*$p<0.05$; **$p<0.01$; ***$p<0.005$; ****$\chi^2 p<0.005$, *****$\chi^2 p<0.0005$, ******$\chi^2 p<0.0001$

TABLE A.9.4

Mean scores and numbers of children functioning below 10th percentile (for respective comparison groups) on school attainment tasks(British Ability Scales) by birthweight grouping - index children and comparison children

	<1000g		*Comparison A*		*95% CI*	*1000g–1499g*		*Comparison B*		*95% CI*
	Mean	*(SD)*	*Mean*	*(SD)*		*Mean*	*(SD)*	*Mean*	*(SD)*	
Word reading	47.9	(11.2)	53.2	(10.6)**	(-9.2, -1.4)	49.9	(11.2)	52.6	(10.9)*	(-4.4, -1.0)
N below 10th percentile	12	(26.7%)	10	(11.1%)		50	(19.6%)	57	(11.4%)*****	
Number skills	40.0	(9.1)	48.9	(10.1)***	(-12.4, -5.3)	45.1	(10.1)	49.2	(10.0)***	(-5.6, -2.6)
N below 10th percentile	17	(37.8%)	9	(10.0%)****		56	(22.0%)	52	(10.4%)******	

*$p<0.05$; **$p<0.01$; ***$p<0.005$; ****$\chi^2 p<0.005$, *****$\chi^2 p<0.001$, ******$\chi^2 p<0.0001$

Appendix 10

A.10 Relationship between performance on Recall of Digits (BAS), General IQ and Word Reading Scores (poor performance for both Recall of Digits and General IQ is defined as > 1SD below the mean)

Table A.10.1

Association between performance on Recall of Digits subscale (BAS), General IQ and Word Reading – index and comparison children

	Word Reading			
	Index Children		*Comparison Children*	
Recall of Digits/General IQ status	*mean*	*SD*	*mean*	*SD*
Recall of Digits poor and General IQ poor	39.4	10.4	41.8	7.8
Recall of Digits poor and General IQ satisfactory	48.2	9.9	48.0	10.6
Recall of Digits satisfactory and General IQ poor	42.8	10.5	43.8	8.4
Recall of Digits satisfactory and General IQ satisfactory	52.8	8.3	54.6	10.4

Table A.10.2

Association between performance on Recall of Digits subscale (BAS), General IQ and Word Reading (ANOVA) and Tukey HSD test – index children

Recall of Digits/General IQ status		(1) N=197 mean=39.4	(2) N=43 mean=48.2	(3) N=32 mean=42.8	(4) N=28 mean=52.8
Recall of Digits poor and General IQ poor	(1)		0.005	0.515	0.000
Recall of Digits poor and General IQ satisfactory	(2)	0.005		0.107	0.075
Recall of Digits satisfactory and General IQ poor	(3)	0.515	0.107		0.000
Recall of Digits satisfactory and General IQ satisfactory	(4)	0.000	0.075	0.000	

Table A.10.3

Association between performance on Recall of Digits subscale (BAS), General IQ and Word Reading (ANOVA) and Tukey HSD test – comparison children

Recall of Digits/General IQ status		(1) N=24 mean=41.8	(2) N=60 mean=48.0	(3) N=35 mean=43.8	(4) N=471 mean=54.6
Recall of Digits poor and General IQ poor	(1)		0.064	0.883	0.000
Recall of Digits poor and General IQ satisfactory	(2)	0.064		0.231	0.000
Recall of Digits satisfactory and General IQ poor	(3)	0.883	0.231		0.000
Recall of Digits satisfactory and General IQ satisfactory	(4)	0.000	0.000	0.000	