The cognitive, perceptual, social, environmental, and developmental factors associated with child language ability

Thesis submitted by

Katrina Ann LINES BPsych (Hons) Qld

in December 2003

for the degree of Doctor of Philosophy

in the School of Psychology

James Cook University

STATEMENT OF ACCESS

I, the undersigned, author of this work, understand that James Cook University will make this thesis available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere.

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and; I do not wish to place any further restriction on access to this work.

____________________________ ________________

Signature Date

STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Signature Date

STATEMENT OF SOURCES

ELECTRONIC COPY

I, the undersigned, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library is an accurate copy of the print thesis submitted, within the limits of the technology available.

Signature Date

DECLARATION ON ETHICS AND THE CONTRIBUTION OF OTHERS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Humans* (1999), the *Joint NHMRC/AVCC Statements and Guidelines on Research Practice* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval number H1144).

The research presented and reported in this thesis was designed by the author (under supervision). The data was collected by the author with the aid of three research assistants, who were remunerated for their services. The data was analysed by the author. The sources of funding for the research were the School of Psychology James Cook University, two *Doctoral Merit Research Grants* from James Cook University, and the author.

______________________________ _______________________

Signature Date

ACKNOWLEDGEMENTS

In any undertaking of size there are people whose contribution is invaluable to its successful resolution, and this research and thesis are no exception. Firstly, I would like to extend my heartfelt gratitude to my supervisor Dr. David Cottrell for his excellent guidance, assistance, support, encouragement and holiday tips during this project. I know that the PhD 'experience' can be stressful for many people, but thanks to David I have survived mostly unscathed, although I can't vouch for those around me.

I would also like to thank Education Queensland, in particular the principals, teachers, students and parents at Hambledon, White Rock, Balaclava, Edge Hill, Bentley Park, Whitfield, Freshwater, Redlynch and Trinity Beach State Schools. Without the willing participation of all of these people, this research could not have been conducted. To the 162 children from these schools who happily (in most cases) underwent the testing, thank you for reminding me that research is about the people involved and not about the numbers generated.

The data collection phase of this research took place over a whole school year and would not have been possible without the help of three research assistants. To Ulrike Darch, David Manners and Avril Reynolds, thank you for your professionalism, adaptability, cheerfulness and sense of fun in working with so many children over such a long period of time, in so many different schools.

No research undertaking occurs without material support and encouragement, for which I would like to thank the staff of the School of Psychology, James Cook University. I would also like to thank my colleagues and co-candidates Donna Goodman and Denise Dillon for their support and welcome constructive criticism, but most especially for the provision of wonderful coffee conversations when I was procrastinating.

Finally, it is difficult to express how much I appreciate my partner, children, parents and friends for never doubting I would achieve this, especially when I had doubts. I dedicate this thesis to Maxine, Imogen and Jordan, three wonderful and special people.

ABSTRACT

Child language ability has been associated with cognitive, perceptual and social/developmental factors including auditory temporal processing, processing speed, cognitive capacity and verbal working memory. These factors have largely been identified through research on children with language impairments. In particular, specific language impairment (SLI) has been viewed as a unique opportunity to study the factors of importance in language development free from potentially confounding factors like intelligence, and social, physical and environmental effects (Leonard, 1998). The main aim of this research was to investigate whether the cognitive, perceptual and social/developmental factors identified in previous research really are important for normal language development as a whole, as the majority of research undertaken has not included children across the full range of normal language ability. In addition, the relationships between language, nonverbal intelligence and social, environmental and developmental factors are not usually considered in research on SLI due to the strict diagnostic criteria. However, these factors are hypothesised to have importance for language ability as a whole and have the potential for relationships with one another. Some task based questions were also examined. These included an investigation of McDonald and Christiansen's (2002) contention that verbal working memory tasks are merely special types of language processing tasks, and predictions arising from Baddeley's (1986) model of working memory. Participants included 158 seven to nine year old children who were administered a battery of language, nonverbal IQ and purpose-made tasks. The children's parents were administered an interview that included their years of education and occupation, and language and physical risk factors for the child. Not surprisingly, results from correlational analyses indicate that most variables are significantly related to language ability. The strongest relationships for language ability were with nonverbal IQ, nonword repetition and the language developmental risk index. As was expected from the correlations, the mean differences between groups with low, average and high language ability reflect linear relationships. However, when the variance from nonverbal IQ or the language developmental risk index was removed from the analyses (via ANCOVA), no results remained significant. This indicates complex relationships between cognitive, perceptual and developmental factors, which were confirmed in the analysis of structural equation models. The best fitting model represented the hypothesis that cognitive capacity would predict language ability and was domain-specific as predicted by Baddeley's theory of working memory. A model reversing the relationship between language and verbal working memory testing McDonald and Christiansen's argument indicated that language ability has a significant effect on all study variables, and an almost perfectly collinear relationship with verbal working memory. The results of the study indicate that: a) multivariate research and analysis approaches are necessary to elucidate the complex predictors of language ability as univariate and quasi-experimental methods do not identify the underlying interrelationships, b) some verbal working memory tasks appear to be measuring language processing as argued by MacDonald and Christiansen, c) it may be impossible to remove the effects of language from experimental tasks, thus requiring novel means of quantifying these effects, and d) that classifying SLI as a distinct disorder may be erroneous as 13% of this non-clinical sample met all criteria for a diagnosis of SLI.

TABLE OF CONTENTS

Title Page i

Statement of Access ii

Statement of Sources - Declaration iii

Statement of Sources – Electronic Copy iv

Declaration on Ethics and the Contribution of Others v

Acknowledgements vi

Abstract viii

Table of Contents x

List of Tables xiii

List of Figures xv

Chapter 1: Introduction and Review of Literature 1

1.1 Description of Specific Language Impairment 5

1.2 The Criteria for a Diagnosis of SLI 6

1.3 The Aetiology of Specific Language Impairment 8

1.4 Temporal Processing Deficiency 9

1.5 Deficits in Information Processing Speed 12

1.6 Disorders of Working Memory/Cognitive Capacity 17

1.6.1 Baddeley's Working Memory Model 18

1.6.2 Connectionist Models of Language and Memory 21

1.6.3 Cognitive Capacity and Relational Complexity 28

1.7 Social, Developmental and Environmental Influences 31

1.8 The Present Research 36

1.9 Significance of the Present Research 44

Chapter 2: Methods **46**

2.1 Sampling Methodology 46

2.2 Rate of Return of Consent Forms 51

2.3 Eligibility for Participation and Exclusionary Criteria 53

2.4 Power Analyses 54

2.5 Description of Child Participants 54

2.6 Matched Sub-Sample Characteristics 59

2.7 Description of Adult Participants 61

2.8 Materials 62

2.8.1 Language Ability 64

2.8.2 Nonverbal Intelligence 64

2.8.3 Global Processing Speed 65

RAN Task 65

Arrow Task 65

Word & Figure Memory Scanning Tasks 67

2.8.4 Cognitive Capacity and Working Memory 70

Nonword Repetition Task 70

The Memory Span Task 71

Cognitive Capacity Tasks 78

2.8.5 Auditory Temporal Processing 82

2.8.6 Social, Environmental and Developmental Factors 84

2.9 General Procedure 88

Chapter 3: Correlational Relationships between Study Variables 92

3.1 Hypotheses 92

3.2 Design and Data Screening 93

3.3 Whole Sample Relationships 94

3.4 Matched Sub-Sample Relationships 98

3.5 Correlational Results and Implications for Study Hypotheses 102

3.6 Discussion of Correlational Findings 104

Chapter 4: Language Ability Group Comparisons 109

4.1 Design and Hypotheses 112

4.2 Description of the Language Ability Groups 113

4.3 Analysis of Variance Results for Between Group Analyses 113

4.4 Analysis of Covariance Results for Between Group Analyses 119

4.5 Analysis of Variance and Covariance Results for Within Group Analyses of the Memory Task 121

4.6 Discussion of Analyses and Hypotheses 124

Chapter 5: Structural Relationships Between Major Research Variables and Language Ability **131**

5.1 Model Development and Hypotheses 134

5.2 Data Screening 142

5.3 Model Analyses 143

5.3.1 The Measurement Model 146

5.3.2 The Direct Effects Model 148

5.3.3. The Global Processing Speed Hypothesis Model 150

5.3.4 The Cognitive Capacity Hypothesis Model 153

5.3.5 The Effects of Language Model 156

5.4 Discussion of Model Analyses and Study Hypotheses 160

Chapter 6: General Discussion, Conclusions, Limitations and Implications **165**

6.1 Normal Distribution of Language Results and Number of Children Meeting the Language and Other Criteria for SLI 166

6.2 Relationships between Cognitive, Perceptual and Developmental Variables and Language Ability 168

6.2.1 The Relationship between Nonverbal IQ and Language Ability 168

6.2.2 The Relationships between Language Ability and Cognitive, Perceptual and Developmental Variables 173

6.3 Tasks with Linguistic Processing Requirements and their Relationships with Language Ability 173

6.4 Direct and Mediated Effects from Social, Environmental and Developmental Factors 175

6.5 Structural Models of Language Ability 176

6.6 Structural Models and Verbal Working Memory 177

6.7 General Discussion 181

6.8 Limitations of the Present Study 189

6.9 Implications of the Study Findings and Future Directions 192

6.10 Significance of the Present Research 197

References **199**

Appendix A: Ethical Approval and Participant Consent Documents **219**

Appendix B: Research Instruction Manual **223**

Appendix C: Parental Interview Proforma, Data Entry Code Book and Language and Physical Risk Index Items **259**

Appendix D: Descriptive Statistics and Additional Data and Analysis Information **269**

LIST OF TABLES

1. Pseudo-Schools, Combined IRSED Score and the Real School Containing the Class that was Sampled from each Pseudo-School 49
2. IRSED, Class Size, Number of Returned Forms and Rate of Return by School 52
3. Demographic, Language and Nonverbal Intelligence Characteristics of Child Participants 55
4. Pearson and Spearman Correlations between Total Language Score, School IRSED, Years of Parental Education and Parental Occupation Code 58
5. Means and Standard Deviations for Low, Average and High Language Ability Groups for Age, Language and Nonverbal IQ 60
6. Demographic Characteristics of Parent/Guardian Participants 61
7. Test and Task Processing Requirements and Associated Latent Variables 63
8. The Structure of the Six Conditions of the Memory Task 72
9. Ranges, Means and Standard Deviations for the Language and Physical Risk Indices for the Whole and Matched Sub-Samples 87
10. The Order of Tests and Tasks Across Participants 90
11. Correlation Matrix for Major Study Variables for *N* = 158 Participants 95
12. Correlation Matrix for Major Study Variables for *N*=30 Participants 99
13. Summary of Between Group Analysis of Variance Results for the Cognitive, Perceptual and Social/Developmental Variables 115
14. Summary of Analysis of Covariance Results for Tasks that Indicated Significant Differences in Performance between Language Ability Groups 120
15. The Standardised Parameter Estimates and Reliability Coefficients for Latent Variables in the Measurement Model 147
16. Comparison of Fit Indices for Model Analyses 161
17. The Interview Items used to Create the Language Risk Index 259

18. The Interview Items used to Create the Physical Risk Index 260
19. Mean Index Scores and Standard Deviations for Low, Average and High Language Ability Groups for the Language and Physical Risk Indices 269
20. Means and Standard Deviations of Reaction Time Scores for Low, Average and High Language Ability Groups for Processing Speed Tasks 270
21. Mean Number Correctly Discriminated and Standard Deviations for Low, Average and High Language Ability Groups for the Auditory Repetition Task 270
22. Mean Number Correct and Standard Deviations for Scores of Low, Average and High Language Ability Groups for the Cognitive Capacity Tasks 271
23. Covariance Matrix for all Observed Variables used in the Structural Equation Models 272
24. Correlation Matrix for the Latent Variables in the Structural Equation Models 274

LIST OF FIGURES

1. The arrow task, showing all configurations. 67
2. The 'yes' stimuli for the figure memory scanning task. 69
3. The 'no' stimuli for the figure memory scanning task. 70
4. Representations of the test windows during the digit span conditions. 75
5. Representations of the test windows during the spatial span conditions. 77
6. Illustrations of the typical screen views in the N-Term task. 79
7. An Illustration of the typical screen view in the Latin Square task. 81
8. The interaction between language ability and number of syllables in the nonword repetition task. 118
9. Correct tone discriminations in the auditory repetition task. 119
10. Mean number of items remembered correctly for type of stimuli in the memory task. 122
11. Mean number remembered correctly for the type of dual task for the memory task. 123
12. The interaction between type of stimulus/response and type of dual task for the memory task. 124
13. The conceptual diagram for the direct effects model. 135
14. The conceptual diagram for the global processing speed hypothesis model. 136
15. The conceptual diagram for the cognitive capacity hypothesis model. 139
16. The conceptual diagram for the effects of language model. 142
17. The direct effects structural model with parameter estimations. 149
18. The global processing speed hypothesis structural model with parameter estimates. 151
19. The cognitive capacity hypothesis structural model with parameter estimates. 154
20. The effects of language structural model with parameter estimates. 156
21. The modified cognitive capacity model - no verbal working memory. 159

Chapter 1

Introduction and Review of Literature

Acquiring language is a fundamental human ability we take for granted. Across all human cultures children acquire their native language in a predictable developmental pattern. This pattern involves relatively invariant stages or milestones. Normal milestones include babbling, the repetition of common consonant vowel combinations, single spoken words, the combination of two or three words and the development of sentence and grammatical structure and lexical diversity. Milestone attainment generally occurs within well-known windows of time, except where cognitive, health, developmental or environmental factors interfere with the process.

As with all human abilities, language acquisition does not occur identically for all children, nor does it result in the same level of ability for every child. Thus, language ability can be characterised along a continuum, with the majority of children attaining a level of ability comparable to their same age peers, and a minority falling above or below this level.

The bulk of developmental language research has focussed on two areas. The first is the normal pattern of language attainment, both for individuals and across cultures. It is from this research that we know the invariant developmental stages all children undergo. The second area, and the most salient for the present study, is research on the characteristics of children who do not acquire language at the same rate or with the same proficiency as other children. Within this area there is a large body of research that has focussed on children who, despite the apparent absence of any physical, social, emotional, environmental or intellectual handicaps do not acquire language normally. These children are often diagnosed as having a specific language impairment (SLI). SLI is a broad term that includes both expressive (spoken language) and receptive (comprehension) impairments. Children diagnosed with SLI may have one or both types of impairment, and symptoms may vary in severity.

SLI has attracted researchers' attention because it is seen as an anomaly in language acquisition, as most language impairments can be readily associated with a cause. For example, deafness causes associated spoken language and reading impairments (Yoshinaga-Itano, Sedey, Coulter & Mehl, 1996). Traumatic brain injury or other neurological insult can result in aphasias (Kolb & Whishaw, 1995) and lower socio-economic status and fewer years of parental education can be related to children's language ability (Tomblin et al., 1997). Similarly, low intelligence is related to lower than average language ability (Leonard, 1987; MacWhinney, 1998; Sattler, 1992). As a diagnosis of SLI precludes alternative causes such as hearing impairments or low intelligence, SLI has offered a unique opportunity to investigate the underlying factors of prime importance in language acquisition (Leonard, 1998).

Research on SLI has also provided a vehicle for the study of language learnability, that is, the argument over whether or not language is innate or learned (Leonard, 1998). Proponents of the theory that language is innate argue that specific grammatical modules in the brain are malformed or do not function adequately in children with SLI (Pinker, 1991). Results from heritability studies and neuroimaging research have been used to support this contention, and linguistic theories proposing modular functions that are impaired in children with SLI have been posited (Pinker, 1991).

In contrast to the innateness theory is the argument that language is learned through exposure, but within heritable constraints (Joanisse & Seidenberg, 1998). Previously the rates of occurrence of the phonological, syntactic, morphological and semantic forms within language that children are exposed to were estimated to be too low for them to adequately learn the underlying grammatical structure (Pinker, 1991; Seidenberg, 1998). However, connectionist models have demonstrated that the rates of occurrence of the structural elements of language during child development are sufficient to enable learning (Seidenberg, 1997).

According to the learnability approach, SLI is an impairment in language processing that interferes with language learning (Joanisse & Seidenberg, 1998). A number of different ways this could potentially happen have been investigated via connectionist models. For example, Dell, Schwartz, Martin, Saffran and Gagnon (1997) modified the efficiency of connectionist networks, while Harm and Seidenberg, (1999) tested the effect of different amounts of units in networks. Evidence from this research has shown that there are a number of potential mechanisms that can affect a network's output and capacity to learn. The consensus from this research is that language ability is a complex interaction between biological factors and exposure to language (Joanisse & Seidenberg, 1998; MacDonald & Christiansen, 2002; Seidenberg, 1997).

Clearly, new avenues of research such as connectionist models are valuable in illuminating the language developmental process, and in future may shed some light on why other non-language impairments also occur in SLI. For example, children with SLI appear to be slower at processing a range of information, both linguistic and non-linguistic (Kail, 1994) and to have difficulties with some motor and cognitive tasks that do not involve language processing (Bishop, 1992, Leonard, 1998). Explanations for these non-language impairments pose a problem for both the innateness and learnability theories of language acquisition. Within the innateness theory of language acquisition there are no mechanisms or processes that explain other types of problems a child with SLI may suffer in comparison to same age peers. All processes are argued to occur in language specific modules that change during development (Pinker, 1991). It is not clear from this approach how language is related to other types of cognitive and perceptual functioning other than through similar developmental processes.

The learnability theory of language acquisition fares better at accounting for other problems a child with SLI may suffer, by including biological and environmental factors. However, the current focus of most connectionist models is on phonological deficits underlying language impairments (Joanisse & Seidenberg, 1998; MacDonald & Christiansen, 2002). A phonological account alone cannot explain why some children with SLI process non-linguistic information slower, or do mental rotation tasks more poorly than same age peers (Kail, 1994; Savich, 1984). However, within a connectionist framework similar types of biological and neurological constraints as those argued to result in phonological impairments might also explain non-linguistic impairments.

Research into the causes of SLI and other language impairments has facilitated the growth of knowledge about how language is acquired. However, it could be argued that it has also raised questions regarding assumptions made about SLI providing an opportunity to isolate language from other cognitive and perceptual processes. Based on the assumption that SLI has provided a unique opportunity to study language ability free from intelligence and other factors (Leonard, 1998), a large body of research has seemingly uncovered the factors that are important in normal language acquisition. However, it is less clear whether this assumption about SLI is correct. Leonard (1998) has argued that children with SLI may not actually suffer a distinct, language-bounded disorder. Instead, they may represent the lower end of the language ability continuum, and that this may not be unrelated to other types of cognitive functioning as is generally supposed. It is this contention, rather than an examination of SLI per se, that is the focus of the present research. However, in order to investigate this argument, it is necessary to review the factors of importance to language development that have been identified by research on SLI and the characteristics of SLI itself.

1.1 Description of Specific Language Impairment

There is a high degree of heterogeneity amongst observed language deficits in children with SLI (Bishop, 1992; Friel-Patti, 1999; Joanisse & Seidenberg, 1998). Children in this population may have speech impairments, difficulty with syntactic constructions such as tense and plurality, slower lexical development, word finding difficulties and conversational inadequacies (Bishop, 1992; Friel-Patti, 1999; Leonard, 1998). Regardless of individual language profiles, most children with SLI will experience reading, writing and other learning impairments once they commence school (Friel-Patti, 1999; Leonard, 1998). In addition, children with SLI are more likely to have concomitant behavioural, emotional and social difficulties (Brinton & Fujiki, 1999; Gallagher, 1999).

Estimates of the prevalence of SLI in children range from 1.5% to 7.4% (Leonard, 1998; Tomblin, Records, Buckwalter, Zhang, Smith & O'Brien, 1997).

The Diagnostic and Statistical Manual of Mental Disorders 4th Edition (DSM-IV, American Psychiatric Association, 1994) estimates the prevalence for expressive developmental language disorder at 5% of American children and the expressive plus receptive subtype at 3%. The most recent and comprehensive study to date screened 7218 American five-year-old children attending kindergarten (Tomblin et al., 1997). Amongst this group the prevalence of SLI was 8% for boys and 6% for girls, 7.4% overall. Interestingly, of the large number of children participating in this study, more than 26% failed the initial language screening measures, but only a small percentage of these were subsequently diagnosed with SLI (Tomblin et al., 1997). Of the children diagnosed with SLI only 29% had previously been identified as having a language disorder. Thus, rates of identification appear to be low, even after children have started formal education.

1.2 The Criteria for a Diagnosis of SLI

In order to identify children with SLI for epidemiological, clinical and research purposes, inclusionary and exclusionary criteria for a diagnosis need to be specified. An early and influential attempt by Stark and Tallal (1981) to promote a standardised approach to group selection for research proposed an operational definition of SLI that was based on inclusionary and exclusionary language and intelligence quotient (IQ) criteria (Plante, 1998; Stark & Tallal, 1981). The IQ criterion involved a standard score on intelligence tests above a cut-off of 85 and was designed to rule out a diagnosis of mental retardation. The language criteria were one of: (a) an expressive language age score at least 12 months beneath mental age or chronological age, whichever is lower; (b) a receptive language age score of at least six months below mental age, chronological age, or the lower of the two; or

(c) a combined language age score of at least 12 months below the lower of mental age or chronological age (Plante, 1998; Stark & Tallal, 1981). In addition, the child must not have suffered other physical, social, or emotional deprivations (Plante, 1998; Stark & Tallal, 1981). These criteria have been criticised on the grounds that the calculation of language age differed for each test of language ability, and that mental age is no longer considered a valid or common score from tests of intellectual ability (Plante, 1998).

More recently, the inclusive language criterion used is a score of equal to, or greater than 1.25 standard deviations below the mean on standardised measures of language comprehension, production, or a combination of both (Leonard, 1998). The exclusionary criteria are extensive in order to eliminate alternative causes of language impairment. The child must pass these criteria: (a) a nonverbal/performance IQ score of 85 or higher, (b) hearing acuity passed at conventional levels, (c) no recent episodes of otitis media with effusion (middle ear infection), (d) no oral structural anomalies, (e) developmentally appropriate oral motor function, and (e) no evidence of impaired social interaction or restriction of activities (Leonard, 1998).

Different versions of the criteria for a diagnosis for SLI have been used by both researchers and clinicians, and have consequently been criticised as not adequately representing individual patterns of disability, and for artificially creating language ability groups for research purposes (Kamhi, 1998; Plante, 1998). Plante argues that the IQ criterion alone excludes those children whose IQ scores fall between the SLI criterion cut-off of 85 and the score of 75 recommended in the DSM-IV (American Psychiatric Association, 1994) as the diagnostic criteria for mental retardation. Similarly, the requirement of language scores significantly below the mean gives an assurance of the level of impairment for a diagnosis of SLI, but excludes that group of children whose language ability is below average and has the potential to cause them ongoing difficulties. This group of children has impairments that are less severe, but still obvious, as evidenced by the number of five year olds who failed the Tomblin et al. (1997) initial screening. They exist in a clinical void and have been ignored in language disorder research to date (Leonard, 1998; Kamhi, 1998).

In addition to excluding some children, perhaps inappropriately, the criteria for SLI strongly rely on standardised scores from language and intelligence tests but without specification of which test to use (Leonard, 1998). This could lead some naive clinicians and researchers to believe that all tests are equal. There are a large number of standardised language tests used for both clinical diagnosis and research group selection. Although language age scores are no longer used as a criterion, different language tests may not evaluate the same aspects of language, and may not have comparable norms, diagnostic ability, reliability or validity (Plante, 1998). Thus, criteria may be superficially the same but significantly different across studies and clinicians (Plante, 1998).

1.3 The Aetiology of Specific Language Impairment

Many hypotheses about the aetiology of SLI have been put forward over the extensive period of exploration of the disorder. Currently, there are numerous proposed causes of SLI ranging from a specific linguistic processing dysfunction to neurological dysfunction, and include a number of purported cognitive and perceptual difficulties. Nevertheless, no definitive underlying cause has yet been discovered for SLI (Bishop, 1992; Leonard, 1998).

Despite the large number of causal hypotheses for SLI, this thesis will focus on the major perceptual, cognitive and developmental explanations. These include: (a) a perceptual deficiency in discriminating and sequencing temporal stimuli (Tallal, 1980), (b) deficits in information processing speed (Kail, 1994), (c) disorders of working memory/cognitive capacity (Gathercole & Baddeley, 1990), and (d) environmental and developmental factors known to affect early language learning (Cacace & McFarland, 1998; Roberts et al., 1998). These four areas of research will be discussed in the following sections.

1.4 Temporal Processing Deficiency

Currently, one of the most influential explanations for language, learning and reading impairments is the temporal processing deficit theory, which suggests that some children suffer a perceptual disorder that prevents them from discriminating and sequencing stimuli that are presented rapidly over time (Tallal, 1980). This deficit has been demonstrated with motor, verbal, nonverbal and visual stimuli in groups of language, learning and reading disabled children (Tallal & Piercy, 1973, 1974, 1975; Waber et al., 2000; Wolff, 2002). However, for children with language impairments it is most strongly associated with auditory stimuli (Tallal, 1980; Tallal, 1999; Tallal & Piercy, 1973, 1974, 1975; Tallal, Miller, Jenkins & Merzenich, 1997; Tallal, Stark & Curtiss, 1976; Tallal, Stark, Kallman & Mellits, 1981). With regard to auditory stimuli, various task paradigms have been used, from discrimination tasks such as the Tallal Auditory Repetition Task (TART, Tallal & Piercy, 1973, 1974, 1975) to masking techniques (Wright et al., 1997).

Generally, early research revealed that children with SLI struggle to detect and differentiate auditory stimuli presented at shorter inter-stimulus intervals (ISIs) of ≤ 300ms compared to control groups (Tallal & Piercy, 1973, 1974, 1975; Tallal, Stark & Mellits, 1985). Research using auditory backward masking techniques has demonstrated that children with SLI and other language impairments have difficulty detecting sounds presented immediately before a broad-band masking stimulus compared to normally developing children (Wright et al., 1997). The children in the control group in this study could readily detect the stimulus tone at 45 decibels. However, the researchers found it necessary to increase the volume of the stimulus tone to 90 decibels before the children with SLI could detect it. Wright et al. (1997) argue that this method can reliably discriminate children with language impairments from children with normal language ability.

However, not all researchers agree that a deficit in temporal processing is an adequate explanation for language disorders. Children other than those with SLI exhibit temporal processing deficits as well. For example, temporal processing disorders have been found in children with learning disorders, children with specific reading disability and in hyperactive children with no observable language impairments (Joanisse & Seidenberg, 1998; Waber et al, 2000; Wolff, 2002). Waber et al., (2001) evaluated children with learning disorders on an auditory discrimination task and found that temporal processing ability was equivalent between impaired and control groups, but that the children with learning impairments made more errors in the task. In addition, research using scalp electrodes to record brain electrical activity from children with SLI and children with non-language learning impairments has demonstrated aberrant evoked response potentials from both groups of children that were consistent with an impairment in perceiving rapid auditory information (Kraus, McGee, Carrell, Zecker, Nicol & Koch, 1996).

The pattern of auditory temporal processing impairment has also been found to be inconsistent within children with SLI (Bishop, 1992; Bishop, Carlyon, Deeks & Bishop, 1999). Bishop, Carlyon et al. (1999) found that no auditory temporal processing measure indicated differences between language impaired and control groups of children, leading the authors to conclude "we found no evidence that auditory deficits are a necessary or sufficient cause of language impairments" (p. 1295). Children in *both* groups demonstrated weak temporal processing. Other researchers have also found that even though some measures discriminate groups of language impaired and control children, some control children also show unexpectedly poor auditory temporal processing ability (Health, Hogben & Clark, 1999; Bishop, Bishop, Bright, James, Delaney & Tallal, 1999).

In addition, children with SLI diagnosed with temporal processing deficits when young often do not have problems discriminating rapid stimuli by the time they are adolescents even though their language problems persist (Bernstein & Stark, 1985; Bishop, 1992; Joanisse & Seidenberg, 1998; Tallal, 1980). It has been suggested that temporal processing deficits occurring at a young age impair language at a critical point in development, although the temporal processing deficit is not present when children are older (Bernstein & Stark, 1985).

Other research has shown however, that very young children with normally developing language can also have problems discriminating rapid stimuli (Bishop, 1992). A possible explanation for this is that rather than being a specific perceptual ability, temporal processing may be a specific example of information processing speed. If this were the case, young children would be expected to process information slower, or to have difficulty processing rapidly presented information, because children's processing rates are slower by a constant proportion than young adult's processing rates (Hale & Jansen, 1994). That is, a child's speed of processing increases as he or she matures. This has been reliably demonstrated with a range of cognitive tasks such as response times, working memory tasks, and memory scanning speed (Cerella & Hale, 1994; Dempster, 1981; Gathercole & Baddeley, 1990).

Thus, from the research conducted to date it is unclear whether temporal processing deficits are an artefact of normal development, a primary disorder, or a characteristic of slowed language learning and/or cognitive development. Similarly, it is unclear whether the temporal processing deficits demonstrated in some children with SLI and other language disorders are a symptom of a general cognitive slowing or of an underlying perceptual impairment.

1.5 Deficits in Information Processing Speed

Previous research on the relationship between processing speed and language ability has shown that children with SLI are slower at processing information over a range of tasks compared to children with no language impairments (Kail, 1994; Kail & Hall, 1994; Leonard, 1998; Wolf, 1997). For example, children with SLI are significantly slower at rapid naming of pictures and word recognition tasks (Leonard, Nippold, Kail & Hale, 1983; Wolf, 1997). Slower responses to memory scanning tasks have also been demonstrated for children with SLI (Sininger, Klatzky & Kirchner, 1989). This pattern of results was expected for tasks with a linguistic content. However, due to similar results with non-language timed tasks, such as line length comparison, Kail (1994) contends that cognitive deficits experienced by children with SLI may not be localised specifically to linguistic processes, but represent a more pervasive cognitive slowing.

In support of this contention, Johnston and Ellis Weismer (1983) found that language impaired children did not differ from normal children in their ability to accurately mentally rotate visual images, however, they were significantly slower at all tasks. Savich (1984) found differences in the ability to anticipate patterns of movement in mental imagery tasks, but no significant differences in the time taken to do the tasks. However, in her instructions to the children, Savich told them accuracy was more important than being fast, which may have had a deleterious effect on the time they took to complete the task.

Kail (1994) re-analysed data from a series of group-difference reaction time (RT) studies of children with SLI and children with normal language abilities. He hypothesised that if children with SLI suffered from a generalised cognitive slowing their RTs would be slower by a constant amount relative to normal children. A constant coefficient *m* would represent the slowing factor for every cognitive process a task demanded. Thus, the equation for a multi-component cognitive task for a child with SLI would be $RT = ma + mb + mc \ldots + mk$ (Kail, 1994). Kail plotted the RTs for children with SLI as a function of RTs of normal children across 22 tasks from five separate studies. The results demonstrated that children with SLI responded to all tasks one-third slower than children with normal language (Kail, 1994). More recently, Miller, Kail, Leonard and Tomblin (2001) found that children with SLI were 14% slower on reaction time tasks than normally developing peers while children with more generalised impairments were 30% slower. However, when individual results were examined, some children with SLI did not exhibit slowing across tasks.

Other research has resulted in findings that are not consistent with the global slowing hypothesis. For example, Lahey, Edwards and Munson (2001) hypothesised that due to the linear relationship between reaction times of children with language impairments and normally developing children, it would be plausible for a linear relation between response speed and severity of language impairment to exist. Post hoc analyses performed on results across a number of tasks, however, did not support such a hypothesis. Thus, the exact nature of the relationship between information processing speed and language impairment is not clear. In addition, the way in which processing speed is related to normal language development is also unclear.

Kail's (1994) method, whilst suggesting a means of comparing groups of children with differing language abilities, does not examine RTs for children other than those with SLI and age-appropriate language. Thus, it is unclear if RTs decrease for children with above average language skills, which would indicate a linear relationship between global processing speed and language ability. Analogous relationships have been demonstrated between inspection time and results on intelligence tests (Nettelbeck & Lally, 1976; Nettelbeck, Edwards & Vreugdenhil, 1986) and reaction time and results on intelligence tests (Jensen, 1993; Miller & Vernon, 1992; Vernon & Kantor, 1986; Vernon, Nador & Kantor, 1985). People recording faster inspection and reaction times score higher on timed, un-timed, verbal and nonverbal tests of intelligence (Deary & Stough, 1996; Jensen, 1993).

In connection with this, individual's scores on the verbal and nonverbal components of intelligence tests such as the Wechsler IQ tests are often highly correlated (Gregory, 1996; Wechsler, 1992). This implies that language and nonverbal intelligence co-exist in a linear relationship rather than as separate cognitive processes. In relation to this, Leonard (1987) has suggested that language ability and intelligence may manifest a linear relationship such that children with language impairments merely represent the lower end of a continuum rather than suffer from a distinct disorder. If this were the case, the global slowing impairments evident in some children with SLI may also be related to poorer nonverbal intellectual functioning.

Although this sounds like a plausible explanation, to date most quasi-experimental research comparing children with SLI and normally developing children has found no difference between groups on nonverbal IQ (for extensive reviews of quasi-experimental findings see Bishop, 1992 and Leonard, 1998). If language and nonverbal IQ are correlated it would be expected that significant differences between groups would be evident.

One potential explanation for the lack of significant differences in quasi-experimental research between children with language impairments and normally developing children on nonverbal IQ scores is that the criteria used to make a diagnosis of SLI may artificially eliminate such a difference. The nonverbal IQ criterion for a diagnosis of SLI is a score greater than 85 on a standardised test. This almost guarantees that there will be no differences in nonverbal IQ between groups as it is actually an effective matching device for nonverbal functioning. As discussed previously, the nonverbal IQ criterion renders a group of children ineligible for a diagnosis of SLI even though they would not meet the requirements for a diagnosis of intellectual disability. This group of children are never included in quasi-experimental studies and therefore, any potential relationship between language ability and nonverbal IQ has not been investigated within the context of language impairment.

Further to this, the nonverbal IQ criterion for a diagnosis of SLI also precludes nonverbal intellectual functioning being investigated as a research variable, along with processing speed and cognitive capacity in language studies. Research on nonverbal intelligence, conceptualised as fluid intelligence, has shown that processing speed, working memory and fluid intelligence are intimately related. For example, Carpenter, Just and Shell (1990) maintain that improvements in working memory underlie age-related improvements in fluid intelligence abilities. These authors argue that working memory ability is critical for good performance on tests of fluid intelligence - that is the ability to solve problems without using prior knowledge (crystallised intelligence). In addition, Kail and Park (1992, 1994) have argued that working memory directly benefits from age-related increases in processing speed.

In an attempt to disentangle these co-occurring cognitive gains, Fry and Hale (1996) assessed processing speed, working memory capacity and performance on Raven's Standard Progressive Matrices (Raven, 1989), a test of fluid intelligence, on a sample of 214 children, adolescents and young adults ranging in age from 7 to 19 years. Using regression and path analysis, Fry and Hale found that processing speed and working memory together mediated approximately 50% of the age-related changes in fluid intelligence. In turn, approximately 75% of the developmental change in working memory ability was mediated by changes in processing speed. Thus, Fry and Hale (1996) argued that:

Even when age-related differences in speed, working memory, and fluid intelligence were statistically controlled, individual differences in speed had a direct effect on working memory capacity, which, in turn, was a direct determinant of individual differences in fluid intelligence. (p. 237)

The findings from research on processing speed, working memory and fluid intelligence suggest a number of relationships that have not been investigated in conjunction with language, largely due to the restrictive exclusionary nonverbal IQ criterion for a diagnosis of SLI. Whilst research has shown that there is a relationship between processing speed and language ability, it is not clear how nonverbal functioning affects either or both. It is also apparent that any discussion about relationships between language, processing speed and nonverbal intelligence must encompass working memory, or as it is sometimes conceptualised, cognitive capacity.

1.6 Disorders of Working Memory/Cognitive Capacity

There have been recent suggestions that a slower speed of processing is indicative of a more generalised impairment in overall cognitive capacity in children with SLI (Lahey, Edwards & Munson, 2001; see Leonard, 1998 for review). Within this view, children with SLI have limited resources to allocate to processing tasks and are thus likely to take longer to process information. There are a number of theoretical conceptions of cognitive capacity. The most commonly cited, and extensively researched is working memory, yet there is still no consensus as to either the functional or architectural aspects of this construct (Montgomery, 2002).

Some investigators regard working memory as a unitary construct (Cowan, 1998; MacDonald & Christiansen, 2002), whilst others posit modular architectural components to account for the functioning of working memory (Baddeley, 1986; Daneman & Carpenter, 1983; Just & Carpenter, 1992; Waters & Caplan, 1996; see Montgomery, 2002 for review). Three working memory/cognitive capacity models that have relevance for the study of language ability and SLI are reviewed in the following sections.

1.6.1 Baddeley's Working Memory Model

The role of working memory in language has largely been investigated through Baddeley's (1986) tripartite model which includes verbal, visual and central executive components. The verbal component of the model is the phonological loop, a short-term, capacity-limited storage buffer for phonological information. The phonological loop permits the entry of new information and an internal verbal rehearsal process refreshes existing information. Another important function of the phonological loop is that it permits accurate representations to be formed of incoming phonological information (Montgomery, 2002). Visual/spatial information is processed in a separate, but similar system called the visuo-spatial sketchpad (Baddeley, 1986). The least understood or elucidated aspect of the model is the central executive component, which is argued to regulate attentional and informational resources for storage, processing and retrieval (Baddeley, 1986; Gillam, Hoffman, Marler & Wynn-Dancy, 2002; Montgomery, 2002).

Following a series of experiments examining the phonological working memory abilities of a group of children with SLI and a group of control children, Gathercole and Baddeley (1990) concluded there were no differences in perception, phonological encoding, verbal rehearsal, or rate of articulation abilities between the groups, but that children with SLI have less capacity to process phonological information than age peers. They hypothesised that potential mechanisms influencing phonological capacity limitations might be poor, 'noisy', or less discriminable representations; or a greater rate of decay of existing representations.

Gathercole and Baddeley's (1990) results have not been accepted unequivocally. For example, other research on the speech/phonological working memory capabilities of children with SLI has suggested that there may be, in some sub-groups, phonological encoding and representational difficulties (Stark & Heinz, 1996; Tallal, Stark & Mellits, 1985). In addition, a study by van der Lely and Howard (1993) found no significant differences between children with SLI and children with normal language on a battery of working memory tasks similar to Gathercole and Baddeley's. The results of this study led van der Lely and Howard to argue that it was unlikely that a single underlying cause for the wide range of linguistic discrepancies between the two groups would be found.

Similarly, in an examination of the verbal and nonverbal memory skills of children with poor language comprehension, Nation, Adams, Bowyer-Crane and Snowling (1999) found that the memory difficulties of children with poor comprehension "are specific to the verbal domain and are a concomitant of language impairment, rather than a cause of reading comprehension failure" (p. 139). Conversely, research by Ellis Weismer, Evans and Hesketh (1999) has demonstrated significant differences between groups of language impaired and normal language children on working memory tasks. Thus, there appears to be disagreement between the conclusions of researchers on the verbal working memory abilities of children with SLI within the constructs proposed by Baddeley's (1986) model.

Recent research has examined the central executive component of Baddeley's (1986) model and the hypothesis that deficits in the ability to organise and allocate cognitive resources may underlie SLI and other language impairments. For example, Hoffman (2001) examined the verbal and spatial working memory domains in children with language impairments and normally developing children with a view to investigating central executive functioning. Hoffman used a task similar to one designed by Hale, Myerson, Hyun Rhee, Weiss and Abrams (1996) to investigate selective interference on memory span for verbal and spatial tasks with both verbal and spatial interference. In the Hale et al. study, verbal interference on a verbal task (digit span) was greater than spatial interference on a verbal task, and spatial interference was greater for the spatial task (Xs on a grid) than verbal interference – in their terminology, a double dissociation. In addition, the verbal interference condition (saying the colour of the X as it appeared) had a slightly enhancing (although non-significant) effect on spatial span results. The authors concluded that "verbal and spatial working memory may be experimentally dissociated through completely selective interference effects" (Hale et al., 1996, p. 237) and that this is consistent with Baddeley's domain-specific model.

The Hoffman (2001) study found similar results to adults for normally developing children. The normally developing children exhibited the double dissociation effect and enhancement of responses by cross-modal interference demonstrated by Hale et al. (1996). In comparison, the children with language impairments showed no enhancement effect from the cross-modal condition. Overall, the impaired children had poorer spatial than verbal memory spans, especially in the cross-modal condition.

Hoffman (2001), and Gillam, Hoffman, Marler and Wynn-Dancy (2002) suggest these findings represent differences in central executive functioning between children with language impairments and normally developing children. The explanation for this conclusion was that children with language impairments do not exploit opportunities to disperse processing across modalities, resulting in "inefficient and ineffective information processing for the language impaired group" (Gillam, Hoffman et al., 2002, p. 40). However, it could also be concluded from the results of this research that children with language impairments have fewer resources to allocate in task conditions which require dual processing rather than an inability to allocate processing resources efficiently. If children with language impairments have fewer resources to allocate they will perform poorly in comparison to children without language impairments on complex tasks. In addition, the fact that children with language impairments had poorer spatial memory spans than normally developing children is difficult to explain given other research claiming that limitations in the phonological loop underlie language impairments. The results of this study suggest that children with language impairments do not only suffer deficits in verbal working memory functioning, but may also suffer visuo-spatial deficits.

To summarise, the findings of research on language impairment using the phonological and central executive components of Baddeley's (1986) working memory model, have resulted in the conclusion that impairments can arise from specific capacity limitations, processing inefficiencies, or both. However, to date the evidence for impairments in verbal working memory and central executive functioning within this model is not conclusive. The cognitive profile of children with language impairments in some of these studies may be better explained by a general capacity limitation, especially when complex processing is required.

1.6.2 Connectionist Models of Language and Memory

In contrast to modular working memory models such as Baddeley's (1986), proponents of connectionist models argue that knowledge in any particular domain such as language, cannot be divorced from the processing of that information (Joanisse, Manis, Keating & Seidenberg, 2000; Joanisse & Seidenberg, 1998; MacDonald & Christiansen, 2002). In particular, MacDonald and Christiansen argue that there is no distinction between linguistic knowledge and linguistic working memory and that tasks commonly used to measure verbal/linguistic working memory are "simply different measures of language processing skill" (p. 36).

A similar contention has been made with regard to tasks purported to measure phonological/verbal working memory. A commonly used measure of verbal working memory is the nonword repetition task. The basis for using nonwords is that they reduce the influence of lexical knowledge on novel phonological representations (Gathercole & Baddeley, 1990), and potential cultural bias (Campbell, Dollaghan, Needleman & Janosky, 1997). However, some studies have indicated that lexical, syllabic and prosodic influences can be apparent for nonword repetition depending on how 'wordlike' the nonwords are, making it possible that prior linguistic knowledge affects the processing of nonwords (Dollaghan, Biber & Campbell, 1993, 1995; Frisch, Large & Pisoni, 2000; Gathercole, Willis, Elmslie & Baddeley, 1991). Gathercole (1995) found that young children (four and five year olds) were less accurate in repeating nonwords rated as low in wordlikeness than they were in repeating nonwords rated as high in wordlikeness, indicating that linguistic information aided their repetition of the nonwords high in wordlikeness.

Even though it is acknowledged within the literature that the nonword repetition task is affected by how wordlike the nonwords are, the task is still referred to as being a phonological/verbal task that is relatively free of long-term lexical knowledge and cultural bias (Campbell, Dollaghan, Needleman & Janosky, 1997; Gathercole & Pickering, 2000). Gathercole and Pickering (2000, p. 379) argue, "in the case of nonwords, of course, there is little opportunity for long-term lexical support … because the items have not been previously encountered". Thus, with little likelihood of "long-term lexical support" it could be argued that there is little or no linguistic influence on the processing of the nonwords, unless the nonwords are high in wordlikeness.

Along with the contentious issue of the type of processing used in the nonword repetition task, the task has also been used to measure different conceptualisations of memory. It is variously referred to as a verbal or phonological *memory* task (for example see Briscoe, Bishop, & Frazier Norbury, 2001), a verbal or phonological *working memory* task (for example see Gathercole & Adams, 1993; Gathercole & Baddeley, 1990; Montgomery, 2002), or a verbal or phonological *short-term memory task* (for example see Botting & Conti-Ramsden, 2001; Gathercole, Hitch, Service & Martin, 1997; Simkin & Conti-Ramsden, 2001).

A potential source of the different terminology used to describe the nonword repetition task is Baddeley's (1986) working memory model itself. In the model, phonological information is held in short-term storage within the auditory slave system for processing. Thus, the task is a verbal/phonological working memory task measuring the short-term storage of phonological information and simultaneous processing for spoken output. In a recent comprehensive review of the literature Montgomery (2002) uses the term verbal working memory to cover the wide range of tasks used in research and the different arguments about the effect aspects of verbal/phonological functioning can have on children's language acquisition and language ability. This broader terminology is used throughout the thesis, and the nonword repetition task is referred to as a verbal working memory task.

Research using the nonword repetition task has shown that the ability to accurately repeat nonwords is strongly related to language ability in children, and is a reliable psycholinguistic marker for language impairment (Bishop et al., 1996; Simkin & Conti-Ramsden, 2001). Deficits of the phonological loop in particular are associated with the impairments characteristic of SLI (Bishop et al., 1999; Bishop, North & Donlan, 1996; Gathercole & Baddeley, 1990; Montgomery, 1995).

Explanations for the poor results on nonword repetition tasks exhibited by children with SLI have centred on basic processes such as degraded phonological input, output or perhaps faster decay of phonological traces (Cowan, 1998). Vance (2001) found that children with SLI only performed more poorly than normally developing children on poly-syllabic nonwords. Following a series of studies using nonword repetition, Vance concluded that the more complex the nonword, the harder children with SLI found it to process. This is consistent with the argument that if children with SLI have a general limitation in cognitive capacity, then complex information, regardless of what form it takes, will be processed poorly in comparison to normally developing children.

Another explanation for the verbal/phonological working memory deficits observed in children with SLI comes from statistical accounts of language learning. Joanisse and Seidenberg (1998) maintain that deficits in phonological processing disrupt processing of language material essential for the generalisation of linguistic structure, pronunciation, vocabulary development and phonological working memory. These authors propose that a basic information processing deficit of phonology, the speech-based code of language, contributes to the speech, grammatical, lexical and phonological working memory deficits identified in children with SLI (Joanisse & Seidenberg, 1998).

MacDonald and Christiansen (2002) make a similar argument with regard to the importance of phonological knowledge. However, these authors contend that the capacity limitations shown in verbal working memory tasks are a reflection of a complex interaction between biological factors (neural architecture) and experience with language. Thus, they argue that "individual differences in language-processing ability within the normal population is due to variation in experience with language", and "biological differences that do exist are not in the capacity of a separate working memory" (MacDonald & Christiansen, 2002, p. 38).

Whilst these authors do not discuss language impairment specifically, their connectionist framework makes clear predictions about how biological factors could interact with language experience to produce impairments. For example, differences in the efficiency with which the network processes information (Dell et el., 1997; MacDonald & Christiansen, 2002), differences in the number of units in the network (Harm & Seidenberg, 1999; MacDonald & Christiansen, 2002; Patterson, Seidenberg & McClelland, 1989), and levels of deficits in the integrity of the input signal are potential factors affecting individual differences and capacity limitations (MacDonald & Christiansen, 2002; St. John & Gernsbacher, 1998).

If connectionist architecture is roughly analogous to neural architecture, then these potential factors correspond approximately to associational/communication problems between neurons, structural differences in the number and/or type of neurons and problems differentiating or processing noisy input. Results of instantiations of these deficits and others on connectionist networks demonstrates that the models are affected as a whole, both in processing and in representation of information (MacDonald & Christiansen, 2002). Thus, although specific deficits can be generated by general degradation (Harm & Seidenberg, 1999), there is no separate working memory that is impaired, rather the entire processing and representational functioning of the architecture is altered.

It is unclear how phonology based connectionist theories, and phonological working memory theories, can explain deficits in non-linguistic representational visual, spatial and imagery tasks that have been observed in children with language impairments, unless both share some common cognitive process. For example, non-linguistic and linguistic information may be processed in different neural architectures, but use similar neural processes that are generally affected in children with language impairment. This would result in a more general capacity impairment, which may manifest itself differently depending on the processing requirements of the task. In addition, if architectural constraints are present for the processing of information in a particular domain such as language, within the connectionist model proposed by MacDonald and Christiansen (2002), it is possible that similar constraints would exist for processing information in other domains.

In support of this contention, Goldberg and Costa (1981) argue that the different neuroanatomical characteristics of the cerebral hemispheres result in predictable consequences for cognition. These authors propose that the right hemisphere, due to a greater amount of associational cortex, has a greater capacity to deal with informational complexity across modes of representation compared to the left hemisphere. In contrast, the left hemisphere is superior in tasks requiring unimodal processing and the storage of descriptive systems. According to Goldberg and Costa, a descriptive system is a code, representational system, or set of rules that can be applied to a particular type of stimuli. They are "superstructures imposed on elementary feature detection mechanisms" (p. 151). For example, learning language is essentially learning a representational system or code, which is relatively invariant "across the members of a given linguistic domain" (Goldberg & Costa, 1981, p. 151).

A proportion of the information human beings process does not exist within language, or any formal system (Goldberg & Costa, 1981). We create our own personal systems to simplify information and make processing more efficient. For example, operations on visual and spatial information do not occur in any formal way as language does, however, it could be argued that the type of mental manipulation and thinking strategies a person uses will affect the simplicity and efficiency of processing. In addition, some descriptive systems that use abstract concepts are culture based (for example mathematics, musical notation etc), and as such may rely heavily on communication from members of the culture and thus have a great dependence on language (Goldberg & Costa, 1981).

It is possible that children with SLI could have a general processing capacity limitation or dysfunction, which manifests itself as an inability to reduce raw information to an efficient code system even after repeated exposure. This proposal is consistent with the connectionist argument in that the neuroanatomical structures associated with the development of descriptive systems will necessarily be subject to biological constraints. In addition, the underpinning of the Goldberg and Costa theory is that experience with information is the process through which code systems are learned or developed. Therefore, according to the neuroanatomical and connectionist approaches reviewed here, both linguistic and non-linguistic tasks could suffer similarly from a lack of experience with such tasks, and individual differences in neural architecture. In addition, whilst allowing for different architectural foci for processing particular information, neither approach endorses domain specific processing capacities.

1.6.3 Cognitive Capacity and Relational Complexity

Another theory of cognitive capacity/working memory, which does not rely on domain-specific processing, is the conception that working memory is the ability to hold information 'in mind' and manipulate it in some manner. If this ability was impaired in some way it would be reasonable to expect deficits in both verbal and nonverbal abilities. Working memory tasks (linguistic and non-linguistic) require a number of cognitive processes to be undertaken in a short period of time. An alternative explanation for the differences found in working memory ability between children with SLI and children with normal language could be that the number of processes a child with SLI can undertake in any given period of time is limited compared to children with normal language ability. This could arise through slower processing speed limiting the number of processes undertaken, or through a limitation in processing capacity. Several capacity limitation accounts of SLI exist (for a review see Ellis Weismer, 1998). The common premise is that the large amount of information to be processed in both the comprehension and production of language, the speed at which these processes must occur, and the time available for processing will determine the success or otherwise of the operation for children with SLI (Bishop, 1992; Ellis Weismer, 1998).

An approach closely related to cognitive capacity is relational complexity (Halford, 1998). The theory of relational complexity attempts to quantify the amount of information that can be processed in parallel at any one time. Halford (1998, 2000) defines this amount of information by the number of relations that need to be processed in order for reasoning, computation or a decision to be made. An example of relational complexity is provided by a dissection of the transitive inference problem. Using the typical A is to B is to C structure of the transitive inference problem, A is to B represents one relation to be processed. A is to B and B is to C, represent two relations to be processed, and A is to B is to C represents three. The problem can be made more complex by adding relations infinitely, however, it appears that the number of dimensions humans can process in parallel is between three and five (Halford, 1998).

As humans mature, or become very familiar with information to be processed, a relation may not be a simple A is to B argument, but may combine a number of sub-relations (Halford, 1998). Thus, experts in a particular information domain will process hierarchically more complex information, even though it can be described as a number of basic relations. An example of this 'chunking' process is the difference in processing capacity between novice and professional mathematicians. When learning mathematics, children will focus on the separate components of basic operations such as multiplication. However, professional mathematicians see a formula containing the multiplication of 5 and 6 and simply see it as 30. The child would have to perform this operation first before working on the rest of the formula if he or she were able. Children become progressively better at processing complex information, both as they become more familiar with the information and as a developmental cognitive process. The ability to process relations follows a similar developmental pattern to speed of information processing, in that children can process fewer relations in parallel than adults (Halford, 1998).

In addition to the relational complexity theory providing a way to quantify cognitive processing capacity, it is congruent with Goldberg and Costa's (1981) theory of cognitive processing discussed in the previous section. Goldberg and Costa argue that experts in any field of information become proficient at seeing the 'code' or relations between pieces of information. Thus, they do not operate on the raw material, but instead use a descriptive system that simplifies and reduces the number of operations necessary. Halford and colleagues (Halford, Wilson & Phillips, 1998) have attempted to quantify the coding process, whilst Goldberg and Costa suggest the neuroanatomical architectures and processes that may facilitate it.

Like Goldberg and Costa's theory, the application of relational complexity is not limited to structured situations such as the transitive inference problem, but is applicable to all simultaneous cognitive processing. The tasks used to measure relational complexity, compared to typical working memory/cognitive capacity type tasks, give a quantitative measure of the number of relations a child can process at a given time. Unfortunately, this theory has not been applied to an examination of children with SLI. It has the potential to be able to quantify differences in cognitive capacity between children with SLI and normally developing children. In addition, it could profitably be applied to an examination of potential relationships between cognitive capacity, language ability and nonverbal abilities.

To summarise, a large body of research arising from competing theories exists to explain the apparent cognitive capacity limitations of children with SLI. It appears these theories all have in common some notion of a processing limitation that negatively influences the performance of children with SLI on any given task, compared to normally developing children. To date there is no research investigating different conceptions of cognitive capacity/working memory and how they relate to language across the range of normal abilities in children, and to other cognitive and perceptual variables.

In addition, cognitive capacity theories that do not rely on domain specific functioning, together with significant differences found between children with SLI and normally developing children on linguistic and non-linguistic tasks, suggest that children with SLI should exhibit lower scores on tests of intelligence, for both the language and nonverbal components. This is because the verbal components of intelligence tests are in effect, special cases of linguistic processing tasks, and the types of tasks in nonverbal tests of intelligence often involve mental rotation and visuo-spatial problem solving. In addition, if a general capacity limitation were present, it would be reasonable to expect that it would negatively affect performance on nonverbal tasks, especially complex ones, as well. However, as discussed in section 1.5 there are generally no significant differences found in quasi-experimental studies between the nonverbal IQ scores of children with SLI and normally developing children in control groups (Bishop, 1992; Leonard, 1998).

Thus, an inclusive analysis of processing speed, working memory, intelligence and language data from a single group of children with a range of language abilities, on both language and non-language processing tasks, would prove beneficial in unravelling the inter-relationships between cognitive capacity, global processing speed, language ability and nonverbal intelligence.

1.7 Developmental, Social and Environmental Influences

Along with cognitive and perceptual theories of language impairment, developmental, social and environmental factors have been hypothesised to influence children's language and learning abilities (Cacace & McFarland, 1998; Roberts et al., 1998; Sattler, 1992). A prime factor in language, reading and academic outcomes for children is the home literacy environment. Foy and Mann (2003) found that exposure to reading related material, a teaching focus on phoneme awareness by parents, and parents' active involvement in children's literature and learning experiences were all directly associated with variables known to be predictive of early reading and phonological ability. Environmental measures in various studies have shown that a significant percentage of reading and academic outcomes for children can be predicted by the home literacy environment, including access to books and reading material, reciting nursery rhymes, and parental modelling of reading and literacy behaviours (Burgess, 2002; de Baessa & Fernandez, 2003; Molfese, Modglin, & Molfese, 2003; Saracho, 2002).

Poor home literacy environments have been related to income and socio-economic factors (Evans, 2004). Children in low-income families are rarely read to, watch more television and have less access to computers and literary material than children in high-income families (Evans, 2004). It has also been demonstrated that children who live in poorer neighbourhoods with a high ambient noise level have poorer language and reading abilities than children who live in more affluent quiet neighbourhoods (Evans & Maxwell, 1997). Low income has also been related to poorer quality of home environments provided for children, leading to poorer quality cognitive stimulation and resulting cognitive competence (Saltaris et al., 2004; Votruba-Drzal, 2003). With regard to SLI, Tomblin et al. (1997) found that lower socio-economic status and fewer parental years of education are related to the occurrence of SLI and Schuele (2001) argues that these factors affect language acquisition in general.

Evans (2004) regards the multiple factors arising from low income and socio-economic status as environmental risks and that such risk exposure is a particularly pathogenic and insidious aspect of childhood poverty. Mackner, Black and Starr (2003) argue that the effect of risk factors associated with low income can be reduced by the use of intervention programs that endorse a child-centred home environment.

In addition to income and socio-economic factors, perinatal risk factors such as prematurity and low birth weight have also been shown to increase the risk of language impairment (Stanton-Chapman, Chapman, Bainbridge, & Scott, 2002). Strathearn (2003) found that the home environments of very low birth weight infants were especially important in ensuring adequate cognitive development. Other perinatal factors known to adversely affect cognitive functioning include maternal drug and alcohol ingestion. Noland et al., (2003) investigated maternal drug use (cocaine, marijuana and alcohol), the home environment and executive functioning in a group of 4-year-old children. The authors found that executive functioning in children was adversely affected by maternal perinatal alcohol and drug consumption when all other variables were controlled. As well as perinatal risk factors, some childhood illnesses can have detrimental acute and chronic effects on children's language development.

An example of such a childhood illness is chronic otitis media, with and without effusion (middle ear infection). This common infection can cause high rates of temporary hearing loss in children (Roberts et al., 1998). For example, in a study of the incidence of otitis media and associated hearing loss, Roberts et al. found mean rates of hearing loss of up to 54.0%. High rates of hearing loss over significant periods of time have been hypothesised to predispose children to auditory perception deficits, verbally based learning disorders, and perhaps interference in integration of visual and auditory stimuli (Cacace & McFarland, 1998).

The types of problems that can occur from recurrent bouts of otitis media are sometimes associated with language and reading impairments. However, the study of the effects of otitis media on language and reading has returned ambiguous results. For example, recent research by Roberts, Burchinal and Ziesel (2002) examined rates of otitis media, associated hearing loss, aspects of the home environment and academic skills during the early primary school years. They found that the child's home environment was the most important predictor of academic outcomes. The authors also found that high incidences of otitis media and related hearing loss resulted in lower expressive language scores in the early years of primary education. However, the children's language scores had reached average levels by the second grade. Thus, the debate over whether otitis media has a deleterious effect on language learning is still unresolved (Roberts & Hunter, 2002). It is likely that a complex interplay of biological and environmental factors influences outcomes for children suffering chronic otitis media.

It is also apparent that both genetic and environmental factors play a role in determining a child's capabilities. Hohnen and Stevenson (1999) found that 40 - 50% of the variance in language ability in six to seven year olds was explained by hereditary factors. However, the small sample size and the large number of variables in this study suggest that these results should be interpreted cautiously. Other research has demonstrated that SLI is highly concentrated in some families, with one particular family having been the subject of much interest as more than thirty family members displayed related language impairments (Bishop, 1992; Gopnick & Crago, 1991; Lahey & Edwards, 1995; Leonard, 1998). Lahey and Edwards (1995) were able to distinguish expressive versus expressive plus receptive subtypes of SLI by differential heritability rates. Those children with expressive disorders were more likely to have a mother, sibling, or other family member who was similarly affected.

In addition to the genetic predisposition to develop a language disorder, it is possible that familial influence also plays an important role in determining a child's achievements. For example, it is likely that the abilities of parents will have a significant effect on their children, but so will the language environment of their home. Stromswold (1998) conducted a large-scale literature review of the evidence for the heritability of spoken language disorders. She concluded that although spoken language disorders seem to cluster in some families, most cases of familial language impairments are the result of a combination of genes and the environment and that the genetic effects evident were not specific to language. Stromswold suggests "there is a synergistic effect between genetic and environment factors, with children who are genetically at risk for developing language disorders being particularly sensitive to subtly impoverished linguistic environments"(p. 306). Thus, it appears that both hereditary and environmental factors play a role in determining whether a child develops a language disorder, however, it is difficult to quantify the importance of each as they seem to be elaborately related.

An example of this type of relatedness comes from studies of the effect of environmental factors alone. It has been demonstrated that the responsiveness of parents affects the quality of verbal interactions with children, as does the number of people living in a house (Evans, Maxwell & Hart, 1999). Evans et al. found that the greater the number of people living together in a house, the greater the detrimental effect on the amount and quality of parent-child interactions. However, Law (1992) maintains that the reverse is also true. Children who are not responsive affect how much their parents interact with them. Thus, it would appear that children are not passive recipients of advances from adults rather, they actively interact with adults and their language varies according to different interaction contexts (Law, 1992).

The evidence from genetic and environmental research suggests that developmental, social and environmental factors are complexly related in normal language development and language disorders. This is consistent with the connectionist model proposed by MacDonald and Christiansen (2002) and Goldberg and Costa's (1981) cognitive processing theory, in which the interaction of biological factors and experience with language has implications for language ability as a whole. Indeed, many of the social, developmental and environmental factors discussed in this section not only have the potential to positively or negatively influence a child's language development, but also to positively or negatively influence neural development.

1.8 The Present Research

The preceding sections reviewed the contribution of the most cogent cognitive, perceptual and developmental theories to the understanding of SLI, a disorder that has been purported to provide a unique opportunity to study the factors of importance for language development in isolation from physical, social, emotional, environmental and intellectual influences (Leonard, 1998). The review of the literature highlights a number of methodological and theoretical issues that need to be addressed if research on SLI is to shed light on language development as a whole.

Firstly, the methodological approach that has been used in most of the research reviewed is quasi-experimental, comparing children with SLI to normally developing children. It has provided an excellent tool for this purpose. Unfortunately, restricting language ability research by relying on the statistical diagnostic criteria for SLI severely limits knowledge of how important cognitive, perceptual and social and environmental/developmental variables contribute to language development as a whole. For example, relying on statistical diagnostic criteria for SLI excludes the children in the language ability range in between those with SLI and those with normal language as well as those on the other end of the continuum with above average language ability.

The criteria for a diagnosis of SLI also places limits on nonverbal IQ, and the group of children with IQ scores above the level for a diagnosis of intellectual disability, but below the cut-off for a diagnosis of SLI have not been included in research on SLI. Thus, little can be said about the relationship between language and nonverbal IQ across the whole range of normal language. Much of the research on language impairment has been confined to an artificially restricted range through the application of statistical criteria. In order to make predictions about what factors actually are important for language ability as a whole, it is necessary to sample across the range of language and intellectual ability evident in a non-clinical group of children. This is a major aim of the present research.

One method of achieving this aim is to use quasi-experimental methodology, which has provided an efficient way of examining the differences between normal children and children with SLI. It is considered that it will also provide a beneficial means of examining the differences between normally developing children. In addition, using quasi-experimental methodology in the present research will enable a comparison between the types of results usually found in research on children with impairments and normal children, and the results from across the range of language ability in a non-clinical sample.

Secondly, within the literature reviewed in this chapter there is the suggestion of potential relationships between a number of factors. Examples include a hypothesised relationship between auditory temporal processing ability and global processing speed, and evidence from studies such as Fry and Hale's (1996) developmental model of working memory, intelligence and processing speed.

Unfortunately, these factors have rarely been investigated together in any structured manner with regard to language ability. An extensive search across diverse fields did not uncover any studies that have attempted to integrate two or more of these theoretical accounts of SLI, and thus language as a whole. Johnston (1991) has argued that trying to link language learning to a single causal variable does not allow investigation "of more complex patterns of association" (p. 77) and that multivariate data are necessary to explore interrelationships and choices between competing theories. The present research aims to examine the relationships between cognitive (nonverbal intelligence, global processing speed and working memory/cognitive capacity), perceptual (auditory temporal processing), social, developmental, and environmental (socio-economic, physical and language development) factors with language ability.

In order to achieve this aim, three different methodologies will be used. These are bivariate correlations, the quasi-experimental examination of language group differences and structural models of language ability. The bivariate correlations will indicate whether or not variables have relationships with language ability as suggested by previous research. Breaking the sample into low, average and high language ability groups and examining the differences will allow investigation of potential linear relationships, and comparison with the results from previous research. The structural models of language ability will test hypotheses about the interrelationships between variables and their importance for language ability.

The third point arising from the review of literature is that many of the theories encompassed give good potential explanations for the language deficits of children with SLI. However, children with SLI also exhibit problems with the mental representation and manipulation of non-linguistic material. These types of tasks are associated with nonverbal intellectual functioning and are often used in nonverbal tests of intelligence. Unfortunately, the theories that attempt to explain both the language and nonverbal problems of children with SLI do not do so successfully. This is because any potential effects of nonverbal IQ are considered to be accounted for by the nonverbal IQ criterion often used for group selection in quasi-experimental studies. For example, either the global slowing or limited cognitive capacity hypotheses could readily explain why children with SLI have problems processing a wide range of information. However, it is difficult to assess the predictions arising from these hypotheses, and their independence (or not) from nonverbal IQ, given the design limitations imposed by the diagnostic criteria for SLI.

Leonard (1998) has suggested that language ability may not be able to be separated from nonverbal functioning, as is the general assumption with SLI. From this perspective it is possible that language and nonverbal functioning are linearly related such that children with language impairments also exhibit lower than average nonverbal IQ scores. However, there is generally no difference between the mean nonverbal IQs of children with SLI compared to normally developing children suggesting that Leonard's contention is erroneous, or there are other explanations for the reliable nonverbal results.

One potential explanation for no differences between children with SLI and normally developing children on nonverbal IQ is that, as mentioned previously, the nonverbal IQ criterion for a diagnosis of SLI assures that a differential diagnosis of intellectual disability is precluded. However, this criterion may also artificially restrict the range of IQ in the group of children with SLI so that no differences between them and normally developing children are apparent, especially if power is limited in small sample sizes. If a non-clinical sample of children is examined on a number of tasks, including nonverbal IQ and others that have been shown to be associated with language in research on SLI, the result may be a set of highly correlated variables. If a number of variables were highly correlated with language, nonverbal IQ, and with each other, a group of children from any normal sample would be expected to perform poorly on most tasks. SLI may simply represent the type of statistical characteristics this group of children who perform poorly embody.

The type of statistical relationship proposed here has been recently identified for a large non-clinical sample of children in a methodological study of the discrepancy criteria for pervasive developmental disorders (Dyck, Hay, Anderson, Smith, Piek & Hallmayer, in press). Dyck and colleagues found that the children who performed poorly on any task, including language tasks, were statistically far more likely to perform poorly on all tasks, and to have related behavioural problems. The group of poor performers had correspondingly low nonverbal and verbal IQ scores. If such a result were to be found in the present research, it would be consistent with Leonard's contention about the abilities of children with SLI and their relationship to nonverbal IQ.

It is a major aim of the present research to investigate the relationship between language and nonverbal abilities suggested by Leonard (1998). A linear relationship between language and nonverbal abilities may become evident in a non-clinical sample of children. If no children in the sample meet the criteria for a diagnosis of SLI this would suggest that SLI is indeed a distinct language impairment. Alternatively, if the lack of a relationship between language and nonverbal intelligence in previous research is a methodological or statistical artefact, then a combination of research methodologies will assist in defining it as such.

The fourth issue arising from the review in this chapter involves the contention that linguistic working memory tasks are special cases of language processing tasks (MacDonald & Christiansen, 2002). MacDonald and Christiansen's argument suggests that explanations for the performances of children on particular tasks such as nonword repetition may be confounded by task demands. Thus, it is not clear whether verbal/phonological working memory tasks are measuring verbal working memory ability or capacity, or whether they are measuring linguistic processing skills.

An aim of the present research is to investigate both MacDonald and Christiansen's claim about verbal working memory and the explanatory value of a model of working memory in structural models of language ability. In order to do this it is necessary to compare working memory capacity tasks, and other types of tasks, with and without linguistic processing requirements. In addition, it would be beneficial to investigate the effects of a range of presentation and response modalities. If tasks with a linguistic processing component are more strongly and reliably related to language ability than other tasks, it may suggest some similarity in task demands, or a domain-specific processing relationship like that specified by Baddeley's (1986) working memory model. Thus, in order to achieve this aim three methodological approaches will be used to examine the relationships between a variety of experimental tasks and language ability.

The final issue raised through the review in this chapter is that developmental, social and environmental factors such as socio-economic status, language environment, family history, and physical and language milestones are often not considered in quasi-experimental research on SLI. Nevertheless, these factors are acknowledged as part of the epidemiological background for the occurrence of SLI (Tomblin et al., 1997), and therefore have importance for language as a whole.

It is a contention of the present research that there are two reasons that make it essential to include these factors in any comprehensive examination of language ability. Firstly, although these factors may be external to many of the theoretical domains discussed in this review, they have relevance for all. This is because developmental, environmental and social factors are potential causes of the cognitive or perceptual deficits associated with language impairments. Thus, it is argued that these factors may be antecedent, or exogenous, to cognitive and perceptual factors such as auditory temporal processing, processing speed or cognitive capacity deficits. Secondly, in addition to possible antecedent effects from these factors to cognitive and perceptual factors, the developmental, environmental and social factors may have a direct effect on language ability. Therefore, two potential types of relationships exist for developmental, environmental and social factors and language ability. These are a) direct relationships, and b) relationships mediated by one or more cognitive and perceptual factors. A further aim of the present research is to investigate these potential relationships.

To summarise, the main objective of the present research is to investigate the factors of importance for language development. These have been identified through a large and diverse body of research on SLI and include cognitive (global processing speed, working memory/cognitive capacity, nonverbal intelligence), perceptual (auditory temporal processing) and social/developmental (socio-economic status, language and physical development) factors. In order to achieve this, the study will take a poly-theoretical and multi-methodological approach, and a number of questions related to the issues discussed in this section will be addressed. The research questions include:

1 Are children who meet the language criterion for a diagnosis of SLI able to be identified in a non-clinical sample of children, and do these children meet any other criteria for SLI, including nonverbal IQ?

2 What type of relationship exists for cognitive, perceptual and developmental variables, across the normal range of language ability in children?

3 What are the relationships and interrelationships between cognitive, perceptual and developmental variables and language ability?

4 Do tasks with linguistic processing elements have stronger relationships with language ability than tasks with little or no linguistic processing requirements?

5 Do developmental, environmental and social variables have direct or mediated effects on language ability?

6 Which structural model, of a number of *a priori* theoretical models of language, such as the cognitive capacity and global processing hypotheses, is the most efficient and parsimonious at explaining language ability?

7 Will an *a priori* structural equation model provide evidence for Baddeley's (1986) domain-specific working memory theory?

8 Will an *a priori* structural equation model provide evidence regarding MacDonald and Christiansen's (2002) contention that verbal working memory tasks are just special types of language tasks?

Each of these questions entails specific hypotheses that are stated in the chapters reporting the study results. The hypotheses are investigated using three approaches to analysis. The first is the analysis of correlational data. The second is examining differences between children in three language ability groups using quasi-experimental methodology. The third approach is the development and testing of *a priori* structural equation models involving all variables and their relationships to language ability. Using three types of analysis facilitates the triangulation and convergence of study results. It will also highlight the type of analysis that provides the most useful information regarding the importance of cognitive, perceptual and social/developmental factors for language ability. Using a multi-methodological approach also enables comparison with a wide range of other research.

1.9 Significance of the Present Research

Research on SLI has been argued to provide an opportunity to study the main factors of relevance for language development. Indeed, without this large body of research on SLI, it would be impossible to identify influential factors in language development. However, to date, no study has attempted to integrate the many factors identified through this research into a cohesive model of language ability. This will be a significant contribution of the present research to the language development field.

In addition, the present research uses a multi-methodological approach to investigate the research questions and hypotheses. This includes testing a relatively large non-clinical sample of children, interviewing parents to obtain developmental, environmental and social information, and using correlational, quasi-experimental and structural modelling analysis techniques.

Thus, the present research significantly extends existing research both theoretically and methodologically. The results of this study will have implications for language development theory and theories of language impairment, in addition to implications for how child language research and research on SLI is conducted.

Finally, the present research has implications for whether developmental impairments such as SLI are characterised as discrete disorders, or are better characterised as syndromes of related impairments and studied in an inclusive, rather than exclusive, manner.

Chapter 2

Methods

2.1 Sampling Methodology

Participants were recruited from third grade classes in Queensland State Primary Schools in the Cairns district. Ethical approval for testing with primary school aged children was granted by the James Cook University Ethics Committee and the District Director of Education Queensland. Appendix A contains copies of the ethical approval documents. Third grade children who were aged seven to nine years were chosen because they are representative of age groups used in previous research, and to accommodate the requirements of available norms for the language and intelligence tests.

Two approaches to determining optimum sample size were used. The first method was to calculate the 99% confidence limits for the measure of language ability in the present study, which is the Clinical Evaluation of Language Fundamentals-III (CELF-3, The Psychological Corporation, 1995). To obtain a level of 99% accuracy tolerating a standard error of measurement of ±3.3, which is the standard error of measurement of the total language score of the CELF-3 (Semel, Wiig & Secord, 1995), a sample size of approximately 137 was required.

However, due to planned multivariate analyses, a sample of approximately 25 participants for each latent variable entered into the multivariate analysis was considered necessary to ensure adequate power to detect a significant effect. There are eight latent variables, thus requiring a sample size of approximately 200 participants. To obtain a sample size within the range of 137 to 200 participants, a target population of approximately 225 third grade children was sought from Cairns State Primary Schools.

There were two problems inherent in obtaining a random sample of third grade children. Firstly, the children who were not included in the sample may have been concerned they had been ‘left out’ or not considered ‘good enough’ for inclusion in the study. Secondly, the process of randomization would have been very difficult given the controls required by the school principals. Education Queensland use clustering and systematic sampling methodology to generate representative samples, which ensures that each child in the district has an equal probability of being sampled (M. Byrne, personal communication, September 10, 2000). Thus, the Education Queensland sampling methodology was deemed appropriate for use in the present study to obtain a sample of third grade children from schools in the Cairns region.

As schools in the region vary greatly in size and socio-economic status, the sample was selected by clustering schools into ‘pseudo-schools’ of a similar number of classes and similar socio-economic level. Thus, the sampling unit was a class, with each class containing 25 children. Nine pseudo-schools were created, most of which contained four classes, while three contained five classes. The extra classes in the three pseudo-schools were randomly removed to leave an equal number of third grade classes per pseudo-school.

Each school in the region is given a socio-economic indicator by Education Queensland. This index is the Index of Relative Social and Economic Disadvantage (IRSED) and is developed from a range of 1996 Census indicators such as the percentage of people in a district who are unemployed. Lower IRSED scores indicate greater disadvantage. The IRSED for each real school was combined and averaged for the pseudo-schools.

The usual procedure once pseudo-schools are formed is to take a systematic sample of classes. However, due to the small number of schools in this region, and the sample size required, the number of pseudo-schools equalled the number of classes needed to be sampled. Therefore, it was planned that a random sample of one class per pseudo-school would be taken to give a total of 225 children in the sample. Thus, nine classes from 16 'real' schools in the region were sampled across socio-economic level. Table 1 indicates the pseudo-schools, their combined socio-economic level and the real school from which the class was sampled.

Each school principal was sent a letter in January 2001 inviting them to participate in the research. The letter included copies of ethical approval from James Cook University and Education Queensland, and a copy of the letter of invitation to parents. The principals were telephoned and an appointment made to discuss the school's participation in the research. All school principals agreed to participate except the principal of Woree State School. Woree State School was already participating in other research, and the principal felt any further projects would involve too great a disruption of teaching time. An alternative school, Trinity Beach State School, was approached and the principal agreed to participate.

The school principals were given an approximate timetable indicating when testing would take place at their school, with the option of choosing when they preferred their school to be involved. The order of testing was: Hambledon State School, Balaclava State School, White Rock State School, Bentley Park College, Edge Hill State School, Whitfield State School, Trinity Beach State School, Freshwater State School and Redlynch State School. Data collection commenced on 3rd April, 2001 and finished on 22nd November, 2001.

Table 1

Pseudo-Schools, Combined IRSED Score and the Real School Containing the Class that was Sampled from each Pseudo-School

Pseudo-School	**Combined IRSED Score***	**The 'Real' School from which the Class was Sampled**
Cairns West + Balaclava	907.001	Balaclava
Parramatta + White Rock	975.722	White Rock
Hambledon + Cairns North	1001.591	Hambledon
Edge Hill + Machans Beach	1005.441	Edge Hill
Woree	1011.621	Woree
Bentley Park	1034.030	Bentley Park
Whitfield + Trinity Beach	1039.593	Whitfield
Caravonica + Freshwater	1050.390	Freshwater
Redlynch + Yorkeys Knob	1052.903	Redlynch

*Lower scores indicate greater disadvantage.

It was planned that a third grade class would be chosen at random from each school. In practice, the principals had already decided which class they would prefer to participate in the research. These decisions appeared to be based on whether the class teacher wanted to participate, how much experience the teacher had, and whether the class contained children the principal and teacher wanted to be assessed. In addition, not all schools had classes containing only third grade children and some schools had only double classes. Therefore, at no school was a class chosen at random; only six schools had single third grade classes; two schools had double classes (50 children, two teachers); and one school had four combined classes of children in first, second and third grade. Whilst this differed from the planned optimum sampling methodology, it reflects the constraints of the environment from which the sample was drawn.

Thus, sampling methodology was flexible in these differing circumstances. For instance, it was considered that targeting only half the children in a double class could create a difficult situation for the teachers and perhaps introduce unintended bias. Therefore, all children in double classes were given an invitation to participate. Similarly, in the mixed grade classes at Whitfield School, all third grade children in each of the four classes were invited to participate.

Consideration was given to the possibility of non-sampling bias arising from differences between parents who allowed their children to participate and those who did not. Therefore, several steps were taken to ensure the optimum rate of participation from each class sampled. These steps included:

1. Asking non-participating parents of children in the same age group as the target population to review the information letter and consent forms before they were issued to participants. Any concerns or questions raised were addressed, and changes were made to the forms at the suggestion of the reviewing parents.
2. An information meeting was offered at each school for parents of the children in the class being sampled. This gave the opportunity for parents to ask questions and examples of the research tasks and tests to be viewed.
3. The principal researcher's contact details were given to all parents along with a comprehensive information letter inviting them to participate.

4. Parents were asked to respond to the information letter by a certain date regardless of whether they wished their child to participate or not.
5. All parents were offered feedback on their child's test results. This was provided in telephone interviews arranged for mutually convenient times.

The original information letters were considered too long and difficult to understand by some reviewing parents and principals. These were altered so they were only one page in length, and contained words of no higher than fifth grade language level. The class teacher distributed the letters to the students. Copies of the information letter and the informed consent form are included in Appendix A.

As mentioned above, meetings were planned for interested parents who wanted more information than was provided in the information letter. This was trialled at Hambledon State School with very poor results: only 1 parent attended. The information meetings were subsequently abandoned due to lack of interest by principals and parents. In addition, asking parents to reply regardless of whether they wanted their child to participate or not seemed to cause confusion, and was also abandoned.

2.2 Rate of Return of Consent Forms

The overall response was 162 returned consent forms out of a possible 290, giving a return rate of approximately 56%. This represents approximately 15% of the total population of children enrolled in the third grade in State Primary Schools in the Cairns district in 2001.

The rate of return was not even across schools. In general, schools with a lower IRSED rating had fewer returned forms than schools with a higher IRSED rating. Table 2 presents the response rate and IRSED details for each of the schools. The lowest rate of return was from Hambledon State School at approximately 17%, and the highest was from Edge Hill State School at approximately 92%. At the lower IRSED schools in particular, the rates of return were congruent with or better than, principals' expectations based on the 'usual' response to letters sent home.

Unfortunately, the difficulty of adhering to the planned sampling methodology, the variability in rates of return of consent forms from different schools and lack of control over some in-school processes are real world constraints on methodology which must be taken into account when examining data from this project. Therefore, results arising from this research must be viewed contextually and be generalised to other populations with caution.

Table 2

IRSED, Class Size, Number of Returned Forms and Rate of Return by School

Schools in Order of Testing	IRSED	Class Size	Number of Returned Forms	Return Rate
Hambledon State School	1001.591	24	4	16.67%
Balaclava State School	907.001	22	5	22.72%
White Rock State School	975.722	23	15	65.22%
Bentley Park College	1034.030	50	28	56.00%
Edge Hill State School	1005.441	24	22	91.67%
Whitfield State School	1039.593	51	33	64.71%
Trinity Beach State School	1039.593	48	22	45.83%
Freshwater State School	1050.390	24	13	54.16%
Redlynch State School	1052.903	24	20	83.33%

2.3 Eligibility for Participation and Exclusionary Criteria

All children who returned a signed consent form were eligible to participate. All who returned forms did participate; however, some children's results were not used in some or all analyses due to several exclusionary factors. It was considered that children would be ineligible to participate in this research if they did not speak English as a first language, had significant perceptual impairments, were severely disabled, ill or on medication that would cause their reactions and motor responses to be affected, or had a history of gross neurological insult.

All children who were eligible to participate spoke English, however, three parents nominated a language other than English as the child's first language. Two children spoke Japanese as their first language, and one child spoke Mong, a Laotian language. Results from these three children were not included in any analyses.

One child had been diagnosed with Autism Spectrum Disorder (ASD) and another with Conduct Disorder. Neither of these children were taking medication for their disorders, however, the child with ASD was receiving special education for his language and learning difficulties. His language problems were at the autistic end of the spectrum, with particular expressive language difficulties. This was reflected in his CELF-3 scores: 84 for receptive language and 53 for expressive language. As the aetiology of this child's language and learning problems was known and was outside of the criteria for specific language disorder, his results were not included in any analyses.

2.4 Power Analyses

There are limited avenues for estimating *a priori* power on a given sample for the purposes of structural equation modelling (SEM). Thus, a multiple regression (MR) model was used as this was considered to provide a good estimate of the power available, as it is closely related to SEM. A power analysis on a sample size of 158 was run using the Power Analysis and Sample Size (PASS, NCSS Statistical Software, 2000) computer program. The PASS program has provision for estimating the power of multiple regression studies given a particular number of variables and an estimated R^2. It was decided that using the total number of measured variables would provide a more conservative estimate of power than using the number of latent variables, or the number of parameters to be estimated in the SEM model. Given these parameters, a sample size of 158 achieves 90% power to detect an R^2 of .25 attributed to 30 independent variables using an F-Test with a significance level of .01. The .01 significance level was chosen as a more conservative indicator due to the power estimation being based on a MR model, not the exact SEM model. The power estimations for the group comparisons using the PASS program range from .67 to 1.00 depending on the analysis.

2.5 Description of Child Participants

Group statistics will be presented separately for 158 child participants and 157 parents/guardians. One parent decided not to participate fully in the parental interview after giving informed consent for the child to participate and the child being tested. In addition, some data is missing from the parental interview where foster parents were unsure of the child's previous history.

Table 3 presents summary descriptive demographic, language and nonverbal intelligence statistics for child participants. The children had an approximate average age of 8 years 2 months, with a range of 7 years 2 months to 9 years 4 months. There was no significant difference in the number of male and female participants $\chi^2(1, N=158) = .025$, $p = .87$, with approximately 50% in each group. There were no significant gender differences in age in months $t(156) = -1.199$, $p = .232$, nonverbal intelligence $t(156) = .834$, $p = .40$, expressive language scores $t(156) = -.161$, $p = .87$, receptive language scores $t(156) = .598$, $p = .55$ or total language scores $t(156) = .199$, $p = .84$.

Table 3

Demographic, Language and Nonverbal Intelligence Characteristics of Child Participants

			M	***SD***	**Range**
Gender	***N***	**%**			
Female	80	50.6			
Male	78	49.4			
Total	158	100.0			
Age at testing (months)			98.39	4.67	88 – 112
Language Scores (CELF-3 Std Scores)					
Expressive Language			93.77	15.54	50 – 125
Receptive Language			101.49	15.01	50 – 147
Total Language Score			97.06	15.11	50 – 134
Nonverbal Intelligence (Standard Progressive Matrices Std Score)			100.54	10.66	79 – 142

With respect to language scores, 22 children (9 girls and 13 boys) scored more than 1.25 standard deviations below the mean of 100 on the CELF-3, 126 children (63 girls and 63 boys) scored within 1.25 standard deviations above and below the mean, and 10 children (5 boys and 5 girls) scored higher than 1.25 standard deviations above the mean. These groups constitute approximately 14%, 80% and 6% of the sample respectively. The difference in the numbers of children above and below the 1.25 standard deviation cut-off may be attributable to (a) bias caused by more parents of children with problems consenting to participation, (b) bias arising from principals choosing classes containing children who the school regarded as having problems, or (c) cultural bias arising from comparing Australian children with the American norms of the CELF-3.

Of the 22 children with below average language, seven (32%) had been diagnosed previously as having speech, language or learning impairments. Therefore, 68% of these children had never been identified as suffering anything more serious than some difficulties with schoolwork.

Of the children with normal language scores, 18% (23) had previously been diagnosed with a speech, language or learning impairment. In this group, most children had been diagnosed as having speech impairments and had completed a course of speech therapy. No child with above average language scores had been previously diagnosed with a speech, language or learning impairment.

Information on whether blood relatives of the children had been diagnosed with speech, language or learning impairments was also gathered. Fifty-six children, or approximately 36% of the sample overall had blood relatives with related problems. This includes 10 children with below average language ability, 43 children with average language ability, and 3 children with above average language ability. These figures represent approximately 45% of the children with below average language ability, 34% of the children with average language ability and 33% of the children with above average language ability, respectively.

The relatives involved were most commonly first-degree relatives such as parents or siblings; however, mention was also made of cousins, maternal and paternal aunts and uncles, and occasionally grandparents. Diagnoses ranged from speech impediments like stuttering, to major language and learning difficulties. A number of families exhibited more than one member with similar or related problems.

Relationships between socio-economic indicators such as school IRSED, years of parental education and parent occupation code with the CELF-3 total language score and the Standard Progressive Matrices (nonverbal IQ) were examined using both Pearson and Spearman correlation equations due to differing data types. Occupation code is an ordinal scale representing occupation types from professional (score of five) through to unemployed (score of one). Appendix C contains the complete list. The Pearson correlation coefficients are appropriate for correlations between CELF-3, the Standard Progressive Matrices (SPM) and years of parental education data; however, parental occupation code is best interpreted through the non-parametric statistic. The correlation matrix of language score, school IRSED, years of parental education and occupation code is presented in Table 4.

The bivariate correlations indicate that the children's language scores were significantly positively correlated with their nonverbal IQ scores ($r = .53$, $p < .01$), the parent's occupation code ($r_s = .35$, $p < .01$), and the number of years of parental education ($r = .26$, $p < .01$). Therefore, a child with an above average language score is more likely to have a parent with a higher occupation code and greater years of education.

Nonverbal IQ was also significantly correlated with parent occupation code (r_s = .22, p < .01), but not with years of parental education (r = .12, *ns*). Years of parental education and occupation code were significantly correlated with each other (r_s = .54, p < .01). This is not surprising given the logical expectation that greater years of education results in the types of occupations given higher codes (see Table 6). The school IRSED was not significantly correlated with language scores (r= -.03, *ns*), nonverbal IQ scores (r = -.15, *ns*), parental occupation code (r_s = .09, *ns*), or years of parental education (r = -.04, *ns*). It should be noted that the IRSED is a school-based score, and is likely to be less sensitive to a child's individual score than his or her parent's occupation or education level.

Table 4

Pearson and Spearman Correlations between Total Language Score, Nonverbal IQ, School IRSED, Years of Parental Education, and Parent Occupation Code

	Nonverbal IQ (SPM)	IRSED	Years of Parental Education	Parental Occupation Code
CELF-3 Total Language	.53**	-.03	.26**	.41**
Score	*.50***	*.03*	*.26***	*.35***
Nonverbal IQ (SPM)		-.15	.12	.22**
	-	*-.08*	*.15*	*.22***
IRSED			-.04	.09
	-	-	*.06*	*.11*
Years of Parental				.62**
Education	-	-	-	*.54***

**p < .01, two-tailed.
Note. Spearman correlation coefficients are in italics.

2.6 Matched Sub-Sample Characteristics

One of the methods used to investigate the relationship of language ability with the cognitive, perceptual and developmental, social and environmental factors was to create comparison groups of children based on language ability. The purpose of creating groups based on language ability was not to emulate previous research on clinically impaired and normal children. Rather, it was to isolate and highlight differences between children and to enable a comparison between the results of the present non-clinical sample and previous research. The extreme ends and the middle of the range of language ability were considered to provide the best opportunity for this.

The language criterion for constructing the groups was based on Leonard's (1998) recommended cut-off for children with SLI of 1.25 standard deviations below the mean for scores on a standardised language test. Thus, the below average language ability group was taken from the pool of children with CELF-3 total scores beneath 1.25 standard deviations below the mean. The average language ability group were taken from the large group of children with scores between 1.25 standard deviations above and below the mean. The above average language ability group were the ten children with scores above 1.25 standard deviations above the mean. The groups will be referred to as low language ability, average language ability and high language ability.

As the high language ability group only contained ten children, the size of the groups was limited. The children in this group were matched for age (to within six months) and gender with children from the other two groups. Surprisingly, only two cases occurred where more than one child could be matched to two other children. In these instances, the child with the closest matching date of birth was chosen. Thus, three groups of ten children (five boys and five girls) were created based on CELF-3 total language scores, for comparison of research variables.

The groups did not differ on age $F(2,27) = 1.72$, $p = .20$, a result expected due to the matching process. Also as expected, the groups differed significantly on receptive language $F(2,27) = 56.70$, $p < .0001$, partial $\eta^2 = .81$, expressive language $F(2,17) = 73.11$, $p < .0001$, partial $\eta^2 = .84$, and total language scores $F(2,27) = 86.79$, $p < .0001$, partial $\eta^2 = .86$. Planned contrasts showed significant differences between all groups for language ability. The means and standard deviations for each group for age, language and nonverbal IQ scores are presented in Table 5.

Table 5

Means and Standard Deviations for Low, Average and High Language Ability Groups for Age, Language, and Nonverbal IQ

	Low Language Ability Group		**Average Language Ability Group**		**High Language Ability Group**	
	M	***SD***	***M***	***SD***	***M***	***SD***
Age (months)	96.90	3.21	96.90	3.35	94.50	3.47
CELF-3 (Std Score)						
Expressive	66.70	10.31	96.80	12.26	118.60	4.70
Receptive	74.30	11.44	103.20	14.49	130.20	8.52
Total	68.90	9.47	99.40	12.75	125.20	4.71
Nonverbal IQ						
(SPM Std Score)	92.20	6.11	98.40	8.96	114.00	6.13

2.7 Description of Adult Participants

Table 6 presents the demographic characteristics of the adult participants.

Table 6

Demographic Characteristics of Parent/Guardian Participants

	N	%	*M*	*SD*	Range
Participating Adult					
Mother	137	87.3			
Father	16	10.2			
Guardian	4	2.5			
Total	*157*	*100.0*			
Occupation (Code)					
Professional (5)	13	8.3			
Semi Prof, Managerial, Technical (4)	38	24.4			
Skilled, Trade, Clerical, Home Duties (3)	85	54.5			
Unskilled Labour (2)	13	8.3			
Unemployed (1)	7	4.5			
Total	*156*	*100.0*			
Family Type					
Single Parent Family	24	15.2			
Two Parent Family	134	84.8			
Total	*158*	*100.0*			
Adult Age in Years	154		36.84	5.36	25 – 59
Years of Parental Education	154		12.29	2.57	3 – 20

Adult participants' ages range from 25 to 59 years, with the mean age approximately 37 years. They also exhibit a wide range of years of education. One participant grew up in Malta where it was considered a waste for girls to continue past three years of schooling, compared to a number of participants who had completed more than one tertiary degree. The mean of years of parental education was 12. The majority of adult participants were mothers. This may result in an underestimation of years of parental education and occupation level based on differences in participation rates for higher education and professional occupations for men and women in Australia (Australian Bureau of Statistics Census, 2001).

2.8 Materials

Table 7 contains an overview of the tests and tasks used in the present research, their processing requirements and the latent variable they are associated with in the structural equation models.

A number of the tasks used were developed specifically for the present research. The task programs were written using either Psyscope, (Cohen, Flatt, MacWhinney & Provost, 1994) software or FutureBASIC[3] (©STAZ Software, 1999) programming language on Macintosh computers. In the interest of standardisation across test administrators, a research instruction manual was developed for both the instructions to participants and procedures to be followed. The research instruction manual is included in Appendix B. In addition, for computerised tasks, the instructions were presented on the screen for the benefit of the person testing the children. The children were told they did not have to read the instructions, and that they were on the screen because "we always forget them" (referring to the testing psychologists and research assistants). Thus, the instructions were read verbatim from either the computer screen or the research instruction manual. Where published tests were used, the instructions were reproduced in the research instruction manual and were also available in the relevant test manual.

Table 7

Test and Task Processing Requirements and Associated Latent Variables

Test/Task/Measure	Latent Variable	Language Processing Requirement?	Presentation Mode	Response Mode
CELF-3 6 Subtests	Language Ability	Yes	Visual and Auditory	Verbal and Motor
SPM 5 subtests	Nonverbal IQ	No	Visual	Motor
RAN Word Figure Arrow	Global Processing Speed	Yes Yes No No	Visual Visual Visual Visual	Verbal Motor Motor Motor
Nonword Repetition Digit Span (3 conds)	Verbal Working Memory	No Yes	Auditory Visual	Verbal Verbal
Spatial Span (3 conds) N-Term Latin Square	Cognitive Capacity	No No No	Visual Visual Visual	Motor Motor Motor
Auditory Repetition Task 9 ISIs	Auditory Temporal Processing	No	Auditory	Motor
Years of Parent Ed Parent Occupation	Socio-Economic Status			
Language Risk Index Physical Risk Index	Developmental Risk Index			

Note. CELF-3 = Clinical Evaluation of Language Fundamentals III; RAN = Rapid Automatized Naming; SPM = Standard Progressive Matrices; ISIs = Interstimulus Intervals; Ed = Education; conds = conditions.

2.8.1 Language Ability

Language ability was assessed with the Clinical Evaluation of Language Fundamentals – III (CELF-3, Semel, Wiig, & Secord, 1995). The CELF-3 gives an expressive language score, a receptive language score and a total language score. The scores are standardised to have a mean of 100 and a standard deviation of 15.

All six subtests required for the calculation of the total scores were administered as appropriate for the child's age. For all children, except two who were over the nine-year-old subtest age threshold, these subtests were Sentence Structure, Concepts and Directions, Word Classes, Word Structure, Formulated Sentences and Recalling Sentences. The two nine-year-old children were administered the appropriate subtests for their age. Sentence Structure, Concepts and Directions and Word Classes combine to create the receptive language score. The Word Structure, Formulated Sentences and Recalling Sentences subtests combine to form the expressive language score. The receptive and expressive scores combine to form the total language score. The testing procedure was carried out as recommended in the CELF-3 Examiner's Manual (Semel, Wiig & Secord, 1995), using the supplied test materials.

2.8.2 Nonverbal Intelligence

Nonverbal intelligence was assessed with the Standard Progressive Matrices (Raven, Raven & Court, 2000). The Standard Progressive Matrices is a series of matrix 'puzzles' that become progressively more difficult. Each matrix has a piece missing. The child must choose which piece completes the matrix from a number of choices. The children's scores were converted to percentiles from age norms, which were then converted to standardised scores with a mean of 100 and a standard deviation of 10.

2.8.3 Global Processing Speed

Global processing speed was assessed by four tasks: Rapid Automatized Naming, a two-alternative forced choice reaction time task and two memory-scanning tasks.

Rapid Automatized Naming Task

The Rapid Automatized Naming task is an optional subtest of the CELF-3. It consists of three conditions, colour naming, shape naming, and colour plus shape naming. The Rapid Automatized Naming task has been demonstrated to discriminate language impaired children from normally developing children (Wiig, Zureich & Chan, 2000). Children with SLI are both slower and less accurate than age peers at the dual task of naming the colour and the shape of the item (Wiig et al., 2000). The task requirements include visual shape and colour recognition, and phonological recoding of this information for a speeded verbal response. Thus, this task has a distinct linguistic processing component. Instructions were given verbatim from the CELF-3 manual. Stimuli were presented via the CELF-3 test booklet.

Arrow Task

The arrow task is a visual task in which children are required to decide whether two arrows are pointing the same or different ways. This task was presented on a Macintosh 1400 Powerbook laptop computer. Participants' reaction times were measured by the speed of their responses to the stimuli by a Carnegie Mellon button box. The children were required to press a green button if they thought the arrows were 'pointing the same way', and a red button if they thought the arrows were 'pointing different ways'.

Stimuli were two yellow block arrows 8cm high and 3cm wide, at the widest point, and separated by 1cm between the widest points. The stimuli were presented in the centre of the computer screen (see Figure 1, which is not to scale). The arrow pairs were presented randomly, across all four possible configurations (both up; both down; right up, left down; right down, left up).

The children were given instructions on how to play the game, and eight practice trials (two of each arrow pair combination). A ready signal, which was a line of stars in 24-point font across the centre of the screen, appeared for 800ms. After the stars the arrow pair appeared for 1500ms, or was terminated by the child's button press response. There were 60 test trials (15 of each arrow pair combination presented randomly for each child). The instructions to participants are recorded in the manual in Appendix B.

The arrow task consists of visual processing of visuo-spatial information (arrows pointing the same or different directions), and recoding of this information to a speeded motor response. Thus, it does not contain any significant linguistic processing requirements apart from understanding key concepts such as 'red' and 'green' (for the buttons on the button box), and the meaning of 'same' and 'different'. To ensure participants understood these concepts, the researchers pointed to the correct button as the instructions were read to the children. In addition, the children were given instructions on what the arrows looked like when they were pointing in the same and different directions. They were also given the opportunity to practice again if they did not understand. No child required further practice and the rate of correct responses on the practice trials was 94%.

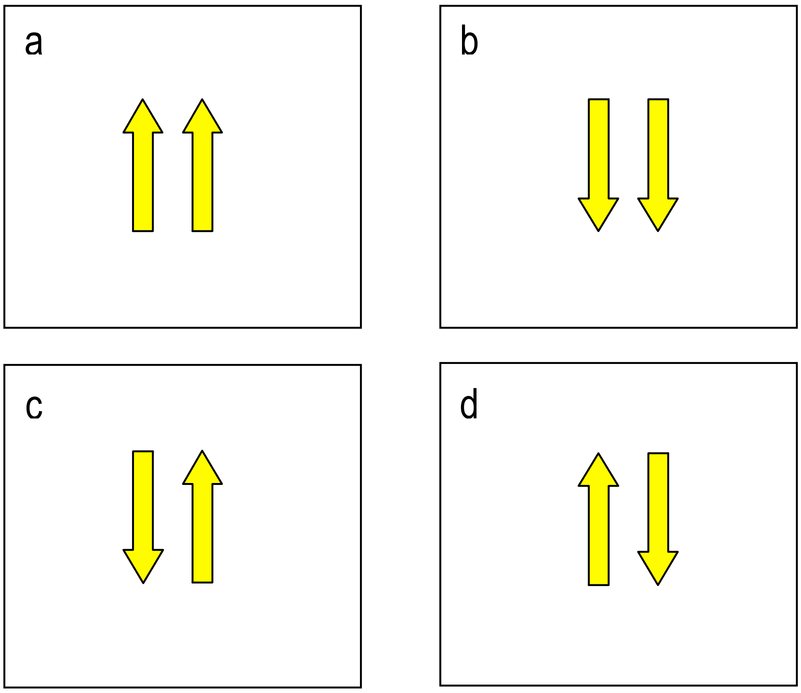

Figure 1. The arrow task stimuli showing all configurations. Figure 1a and 1b illustrate arrows pointing in the same direction, and Figure 1c and 1d illustrate arrows pointing in different directions.

Word and Figure Memory Scanning Tasks

The two memory scanning tasks were Sternberg tasks modelled on the Sininger, Klatzy and Kirchner (1989) task that reduces memory load for children. One of the tasks uses word stimuli that require linguistic processing by the participant, and the other uses random shape stimuli specifically designed to be difficult to associate with a word label. The tasks were designed in this way to contrast the reaction time performance given the different task demands. The tasks were presented on a Macintosh 1400 Powerbook laptop computer. Response type (correct, incorrect) and reaction time were recorded with a Carnegie Mellon button box and automatically recorded in individual data files.

The word stimuli were presented in the centre of the computer screen in uppercase bold 48-point font. The figure stimuli were also presented in the centre of the computer screen and were approximately 8cm in height, though of varying widths. The list stimuli were presented for 1200ms each. After the list, a line of stars appeared in the centre of the screen as a cue that the next word/figure would be the one that the child had to decide was, or was not, in the list just presented. The stars appeared for a duration of 1500ms, the probe stimulus appeared and stayed on the screen until the child responded by pressing a button. There was an interval of 1000ms between the response to the memory probe on one list, and the start of the next list.

The procedure for both memory scanning tasks was identical. The children were given four memory trials in which to learn the 'yes' stimuli, thereby reducing memory load. If a child couldn't remember the stimuli after four trials, he or she was given the opportunity to practice as many times as was necessary. The majority of children could remember the stimuli after the memory trials.

For practice and test trials, the stimuli were presented in lists of two, three and four words or figures. Stimuli lists and 'yes' and 'no' conditions were presented randomly for each participant across one practice trial for each condition and list type and eight test trials for each condition and test type. A total of 72 trials were presented. The word task used monosyllabic first grade reading level words supplied by Education Queensland. The 'yes' stimuli were: *run, dog, home, tree*. The 'no' stimuli were: *good, sun, boy, stop*. The figure task used 8, eight-sided random figures with equal complexity and association value (Vanderplas & Garvin, 1959). The original Vanderplas and Garvin figures were scanned, saved as picture files, enlarged and the definition enhanced. Illustrations of the 'yes' figures are presented in Figure 2, and illustrations of the 'no' figures in Figure 3.

Figures with low association value (Vanderplas & Garvin, 1959) were chosen in order to reduce the likelihood that shapes could be easily labelled, and thus reduce the possibility that completing the task was in part reliant on language processes.

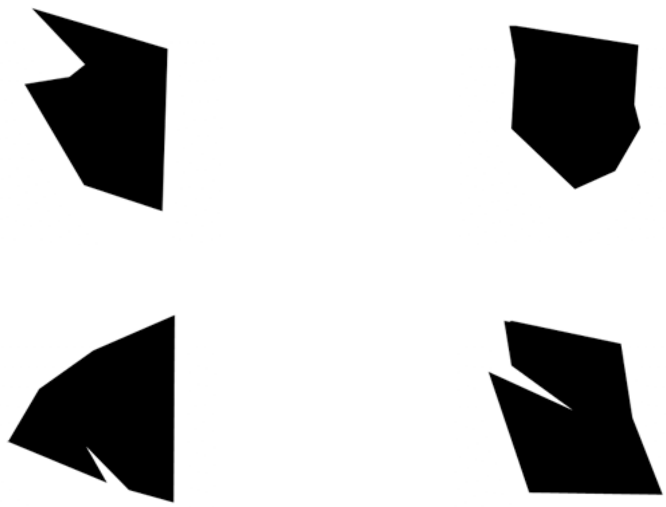

Figure 2. The 'yes' stimuli for the figure memory scanning task.

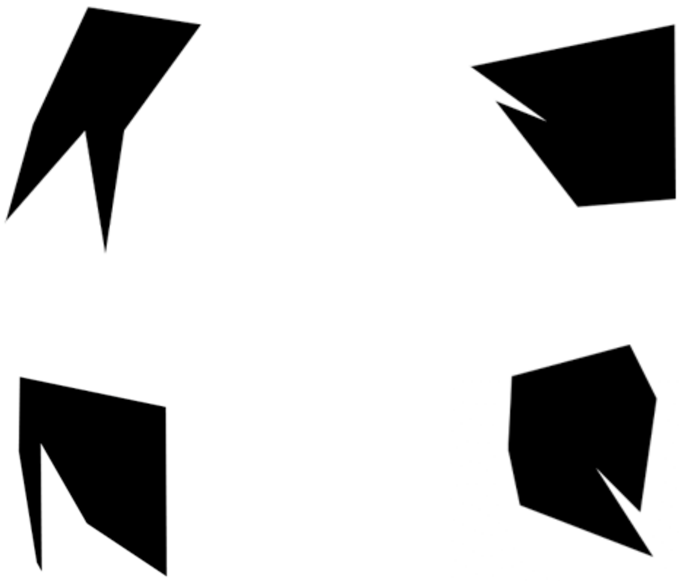

Figure 3. The 'no' stimuli for the figure memory scanning task.

2.8.4 Cognitive Capacity and Working Memory

The cognitive capacity/working memory tasks used in the present study were a variety of tasks measuring different theoretical applications of working memory and cognitive capacity. These are nonword repetition (phonological working memory), digit and spatial span with and without verbal and spatial interference (phonological recoding, visuo-spatial span, central executive functioning) and two tasks measuring the number of relations a child can process at one time (relational complexity/cognitive capacity).

Nonword Repetition Task

To assess phonological working memory, the children were administered the nonword repetition task (Campbell, Dollaghan, Needleman & Janosky, 1997). Stimuli consist of 23 nonwords ranging from one to four syllables in length. There were five one syllable words and six each of two, three and four syllable words. Each nonword was digitally recorded using a dB Technologies CRI-86H-W microphone connected to a Macintosh computer. The single files were combined into one Psyscope (Cohen, Flatt, MacWhinney & Provost, 1994) computer program, which presented the nonwords randomly for each participant at 5s intervals. Participants heard the nonwords presented by a Macintosh 1400 Powerbook via KTX SP-330B speakers. Their repetitions of the nonwords during the inter-stimulus interval (ISI) were recorded on an Optimus CTR-116 N26 voice recorder for later scoring. The principal researcher scored all participants' responses for number of phonemes correct. A random sample of 20 (12%) participants' responses to the task was checked for scoring accuracy by another researcher. Inter-rater reliability was .98.

The dependent variables for the nonword repetition task were the number of correct phonemes for each of one, two, three and four syllable nonwords and for the task as a whole. The number of possible correct phonemes differed depending on how many syllables the nonword contained. The score range for the possible number of correct phonemes for one syllable nonwords is 0 – 15. The possible range for two syllable nonwords is 0 – 37, for three syllable nonwords is 0 – 35, and for four syllable nonwords is 0 – 53.

The Memory Span Task

The memory span task is a modification of that developed by Hale et al., (1996) for use with adults, and also Hale, Bronik and Fry (1997) and Hoffman (2001) for children. The task was modified so that it was presented by computer with responses via the computer mouse and data collected by the program. The task involved the visual presentation of two types of stimuli with matching responses, with and without two types of interference. The stimuli are digits and Xs in a grid, presented one at a time on a computer screen. The responses are verbal and spatial, as are the interference conditions. There were six task conditions: Digit span with no interference, digit span with verbal interference, digit span with spatial interference, spatial span with no interference, spatial span with verbal interference, and spatial span with spatial interference. Thus, the structure of the task is a two (type of stimuli: digits and Xs) x three (interference: none, verbal and spatial) x two (type of response: verbal and spatial) design, which is represented in Table 8.

Table 8

The Structure of the Six Conditions of the Memory Span Task

C[a]	Dependent Variable: Number of Digits Recalled in the Correct Order			Dependent Variable: Number of Xs Recalled in the Correct Order and Correct Position on Grid		
	S[b]	**I[c]**	**R[d]**	**S[b]**	**I[c]**	**R[d]**
1	Digits	None	Verbal	Spatial	None	Spatial
2	Digits	Verbal	Verbal	Spatial	Verbal	Spatial
3	Digits	Spatial	Verbal	Spatial	Spatial	Spatial

[a] Condition, [b] Stimulus Type, [c] Interference Type, [d] Response Type.

The task was computerised in FutureBASIC[3] (©STAZ Software, 1999) and visually presented on a Macintosh 1400 Powerbook laptop with attached extra Macintosh monitor. The participants viewed the attached monitor, while the researcher controlled the program on the laptop keyboard. For the digit span conditions, the child responded verbally with the list of digits he or she saw, in the correct order. The researcher recorded the child's responses on the laptop keyboard.

For the spatial span task, the child recorded his or her responses by clicking in the appropriate squares of the grid on the computer screen.

The computer scored the child's responses at the time of entry for both stimuli. This was to calculate whether the program should present a longer list, the same list length again, or cease altogether. This is important as the presentation of stimuli lists is based on the digit span protocol from the Wechsler Intelligence Scale for Children – III (WISC-III, Wechsler, 1992). Thus, starting at two digits or Xs, lists at each length are presented twice to participants. Stimuli cease when participant's responses are incorrect for both presentations of a given list length.

Although the design of the task presentation followed that of the WISC-III (Wechsler, 1992), a different scoring system was used. The WISC-III measure of digit span is an age corrected standardised score based on the final list length a child responds to correctly for *both* presentations. It does not take into account any list lengths the child remembers correctly for only one presentation. In the present study the measure for each condition is the number of correctly remembered lists regardless of the list length remembered. That is, the score more accurately reflects how many lists the child could remember. The digit and spatial span measures used in the correlational analyses and analyses of variance is the number of lists remembered correctly for the no interference condition only. There are different processing requirements and constraints in the interference conditions that were not considered appropriate for these analyses, but are specifically analysed in a comparison across the task conditions (see Chapter 4). For the structural models two combined scores were constructed which included the number correct from each of the digit span conditions and each of the spatial span conditions. These combined variables were included in the verbal working memory and nonverbal cognitive capacity variables respectively.

In the memory span task the digit stimuli (0 - 9) are in 72-point font and are randomly presented without replacement in any single list. Digits appear on the right side of a rectangular test window for a duration of 1275ms, with a 250ms ISI. After the cessation of the digit list there is a 250ms delay before a memory prompt, which is a computer generated beep. The digits are black in the no interference condition and appear randomly without replacement in any single list in the colours green, pink, blue, yellow and red in the verbal and spatial conditions.

The spatial stimulus consists of a four by four grid on the right hand side of a rectangular test window. The grid cells measure 48 by 48 pixels each. The Xs in the spatial task are randomly presented in grid cells without replacement in any single list. The Xs measure 42 by 39 pixels and are presented for 1275ms with an ISI of 250ms. As in the digit task, there is a 250ms delay between the offset of the last item and the memory prompt (beep). The Xs are black in the no interference condition and appear randomly without replacement in any single list in the colours green, pink, blue, yellow and red in the verbal and spatial interference conditions.

In the digit span with no interference condition (Panel A of Figure 4), black digits are randomly presented in lists starting at two digits long. Once the stimuli have ceased, and the memory prompt occurs, the participant is required to report the digits in the order he or she saw them.

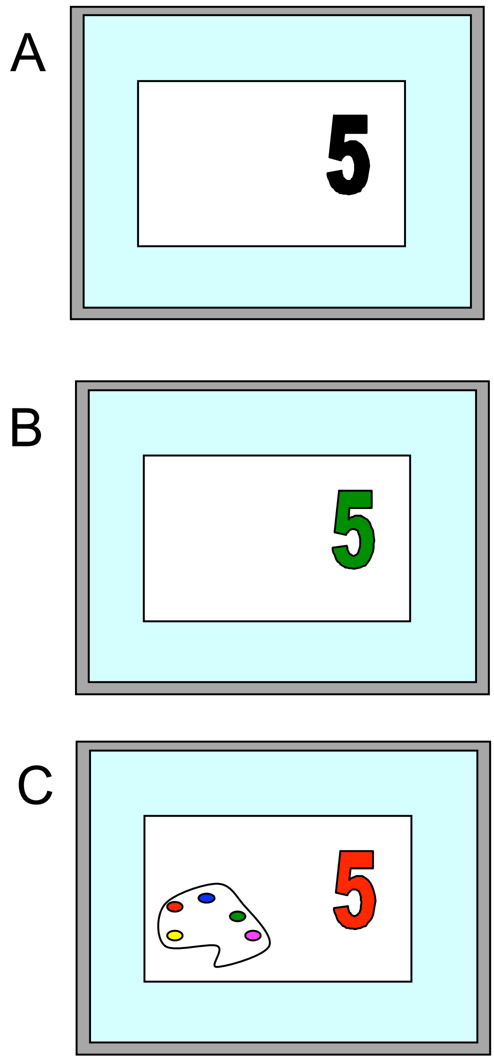

Figure 4. Representations of the computer test windows during the digit span conditions. Panel A represents what the child sees on the computer during the digit span no interference condition, Panel B represents what the child sees on the computer during the digit span with verbal interference condition (says the colour of the digit as it appears on screen), and Panel C represents what the child sees on the computer during the digit span with spatial interference condition (points to the colour of the digit as it appears on the screen, using the mouse and the palette).

The digit span with verbal interference condition (see Panel B of Figure 4) has the same requirements as the no interference condition, but also requires the child to name the colour of the digit out loud as it appears on the screen. The children do not have to report the colours after the stimuli list has been presented, only the digits in the order in which they saw them.

The digit span with spatial interference condition (see Panel C of Figure 4) has the same basic requirements of the no interference condition. In addition, this condition requires the child to point to the colour of the digit with the computer mouse whilst the digit is visible. A 'painter's palette' consisting of the colours green, pink, blue, yellow and red appears on the screen to the left of the digits. After the memory prompt, the child reports the digits in the order in which he or she saw them.

The spatial span with no interference condition (see Panel A of Figure 5) consists of a four by four grid of squares on the computer screen in which black Xs appear one at a time randomly in the grid cells. The stimuli appear in lists starting at two presentations of Xs within the grid. After the stimuli cease, and the memory prompt occurs, participants are required to click the squares (with the computer mouse) in which the Xs appeared, in the correct order of appearance. The computer automatically records the responses for the spatial task via the computer mouse.

The spatial span with verbal interference condition (see Panel B of Figure 5) involves the same requirements as the no interference condition, but also requires the child to report the colour of the Xs out loud as they appear on the screen. After the memory prompt, the child is only required to click on the grid cells where the Xs appeared, in the order they appeared.

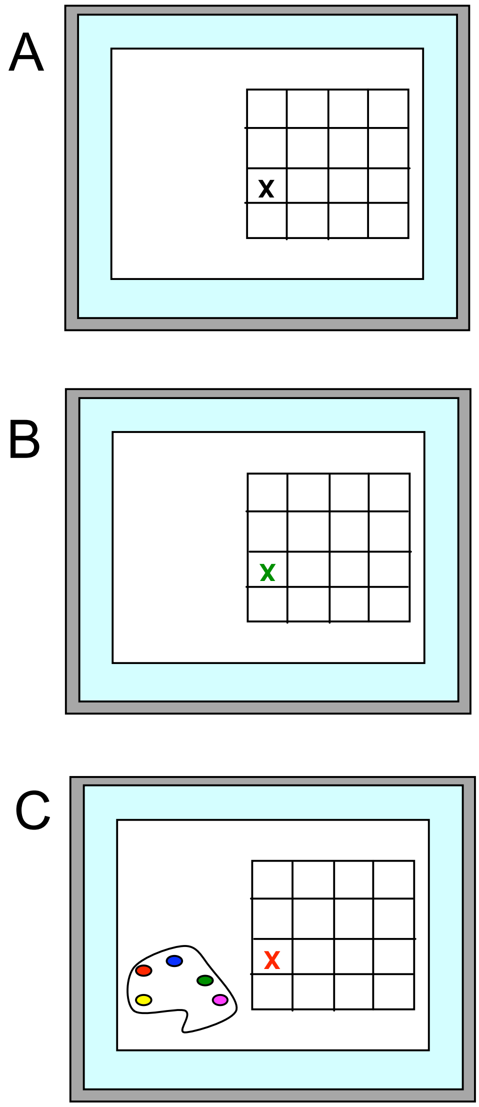

Figure 5. Representations of the test windows during the spatial span conditions. Panel A represents what the child sees on the computer during the spatial span no interference condition, Panel B represents what the child sees on the computer during the spatial span with verbal interference condition (says the colour of the X as it appears in the grid), and Panel C represents what the child sees on the computer during the spatial span with spatial interference condition (points to the colour of the X on the palette with the mouse, as the X appears on screen).

The spatial span with spatial interference condition (see Panel C of Figure 5) also involves the same requirements of the no interference condition. However, like the digit span with spatial interference condition, the children are asked to point with the computer mouse to the colour of the X (as it appears on screen) on a palette on the left of the computer screen. Once the stimuli cease, the participants are only required to click on the grid cells where the Xs appeared, in the order they appeared.

The first trial in each condition of the memory span task was a practice trial. If the child did not understand the task after explanation and practice, the program was restarted so he or she could practice again. Only four children requested more practice.

Cognitive Capacity Tasks

Two tasks that measure cognitive capacity were included in the test battery. Cognitive capacity was defined as the number of relations a child can process in parallel at any one time (Halford, Birney & Andrews, 2000; Halford, Wilson & Phillips, 1998). These tasks were presented on a Dell Inspiron 3700 laptop computer. The N-Term task is a computerised task developed by Halford and colleagues based on the transitive inference problem. Participants are given instructions and practice in deciding which of three coloured squares should go at the top, middle and bottom of a tower based on 'clues' or rules given in picture form at the top of the computer screen (see Figure 6).

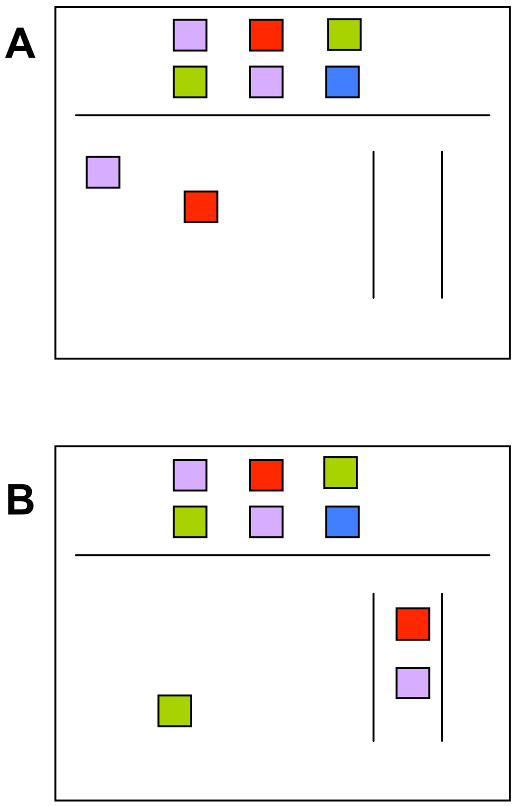

Figure 6. Illustrations of typical screen views in the N-Term task. In both panels, the squares above the upper horizontal line are the task 'clues' or rules. In this case, the clues indicate that purple must be higher than green in the tower, red must be higher than purple in the tower and green must be higher than blue in the tower. In Panel A the child is presented with two blocks that he or she must place in the correct positions in the tower with the computer mouse. Once the blocks are placed in the tower, the child is then presented with another block (Panel B). The child must then decide whether that block should go at the top, middle or bottom of the blocks already in the tower.

The rules exemplify the typical A is to B is to C structure of the transitive inference problem, where A is to B, and B is to C represent two relations to be processed, and A is to B is to C represents three. The N-Term task presents coloured squares configured in these classic relationships. For example, for a binary problem, the pictorial rules may be a blue square on top of a red square (A is to B), and a red square on top of a green square (B is to C). The child has to decide from the rules the order the coloured squares should appear in a tower. For this example, the blue square would go on the top, the red square in the middle and the green square on the bottom. The N-Term task can continue past binary and ternary items to more complex relationships at the quarternary and quinary levels. For the present research, the program was stopped at the end of Phase 1 after the ternary items. This was done because during pilot trials of the program no child could successfully complete the higher-level items and if the children attempted these, it lengthened the time the task took considerably.

The N-Term program provides two practice trials for the binary and ternary levels. The majority of children completed these practice sessions easily. If a child did not understand the task he or she was allowed more practice. Two children asked to repeat the practice trials. Once the practice trials are successfully completed, the program randomly presents 12 test trials (six each of binary and ternary trials). The task program records a range of different data for each participant, however, for the purposes of the present research, the dependent variables were the number of correct trials for binary and ternary relations, and for the task as a whole.

The second cognitive capacity task, which was also developed by Halford et al. (2000), was a computerised version of the latin square task. The child must decide which symbol will correctly complete a cell of a latin square that contains a question mark. The problems are varied instantiations of the rule

$$\text{IF}\{a, b, c, d\} \text{ and } \{a, b, c\} \text{ THEN } \{d\}.$$

Thus, the single rule to solve the latin square is that every symbol may only appear once in every row or column (see Figure 7). The problems represent binary, ternary and quarternary levels of complexity, based on the number of cells in the latin square and the information given in the cells of the latin square. As for the N-Term task, the dependent variables are the number of correct responses for each relational complexity level and for the task as a whole.

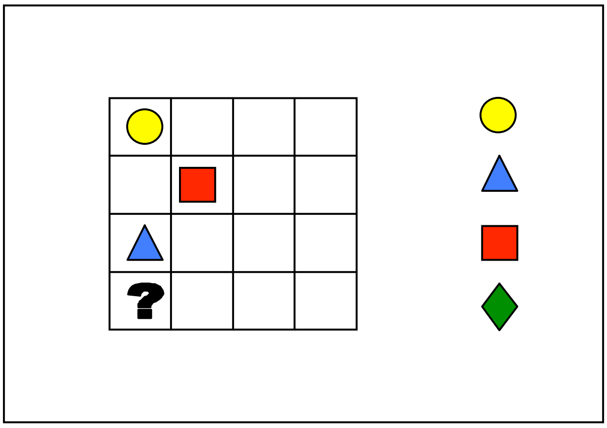

Figure 7. An illustration of a typical computer screen view in the Latin Square task. The rule to completing the problem is that only one of each symbol can be in any row or column. In this case, only the red square can fill the cell with the question mark. This is because, if the rule is followed, only the green diamond can fill the other blank cell in the *column* containing the question mark, because in the *row* containing that blank cell, there is already a red square, so a red square cannot be placed in that *row*. Thus, the green diamond would have to go in the blank cell without the question mark in the column, leaving only the red square left for placement in the cell with the question mark.

The participants were given verbal instruction in how to 'play the game' and practice at the task. The practice trials started at a very simple 1 x 3 matrix of cells illustrating the rule for solving the latin square. Subsequent practice trials gave practice in 3 x 3 and 4 x 4 matrices. If the child failed the practice trials, the test trials were not presented automatically and the practice trials had to be repeated. Four children failed all three practice trials and had to have repeat practice. Once the practice trials are completed successfully, the program randomly presents eight each of binary, ternary and quarternary problems.

2.8.5 Auditory Temporal Processing

The auditory repetition task was modelled on the Tallal Auditory Repetition Task (TART, Tallal & Piercy, 1974; Tallal, Stark, Kallman & Mellits, 1981) and presented on a Macintosh 1400 Powerbook laptop computer. As in the Tallal and Piercy study, the stimuli are two complex 10ms gated tones, one with a fundamental frequency of 100Hz (tone 1) and the other with a fundamental frequency of 305Hz (tone 2). The tones were created using SoundEdit™16 (Version 2.0.7; ©Macromedia, Inc., 1987-1997) and saved as individual sound files. The individual files were then used in the creation of tone pair combinations at ISIs of 10, 30, 60, 120, 180, 240, 300, 360 and 420ms. There are four possible tone pair combinations: Tone 1 then tone 1, tone 2 then tone 2, tone 1 then tone 2, and tone 2 then tone 1.

The auditory repetition task developed for the present research has four conditions, detection, discrimination, sequencing and rate processing. In the detection condition, the children are initially trained using an operant conditioning paradigm, to press the green button on a button box when they hear tone 1. The tone is presented 24 times and the child responds by pressing the green button after each presentation. As in the Tallal and Piercy (1973; 1974) studies, the children were verbally (after every response) and physically (given stickers at the end of the 24 presentations) rewarded for correctly pressing the green button. The same operant process was followed to train the child to press the red button for tone 2.

Once training was completed, a discrimination session was given in which the child received feedback on his or her responses to the presentation of tone pairs. In this condition, the four tone combinations were played twice, in random order at 420ms ISI. The child must listen to the two tones, then press the buttons that correspond to the tones in the order in which they were heard. For example, if the stimulus order is tone 1, tone 1, the child should respond by pressing the green button twice at the end of the stimuli. After the child responded to the stimuli there was a 2000ms interval before the next stimulus pair started. During this session the researchers gave feedback on every response.

After the discrimination session, the eight 420ms ISI tone pairs were presented again (randomly) in the sequencing session. However, in this session, the child responded without assistance.

In the final session, rate processing, the tone pairs were presented randomly two times across all four possible two-tone combinations at 10, 30, 60, 120, 180, 240, 300, and 360 milliseconds interstimulus intervals (ISI). Thus, in the sequencing and rate processing conditions, the child responds to a total of 72 random presentations of tone pair combinations across all ISIs. The computer program collected data automatically via the Carnegie Mellon button box. Response type (correct, incorrect) was recorded for each tone in the tone pairs, giving a total of 16 responses for each child at each interstimulus interval. The dependent variable is the number correct for each interstimulus interval.

2.8.6 Social, Environmental and Developmental Factors

Social, environmental and developmental factors were assessed using measures of socio-economic status and measures of language and physical risk that included developmental risk indicators. Previous research has shown that developmental factors such as language and motor milestones, perinatal factors, early home literary and social environments, socioeconomic factors and childhood illnesses (Burgess, 2002; Evans, 2004; Noland et al., 2003; Roberts et al., 1998; Saltaris et al., 2004; Stanton-Chapman et al., 2002; Strathearn, 2003) can be associated with later language and cognitive problems. However, not all children who are exposed to these environmental events, or who display delayed language or motor milestones, or who experience low socioeconomic backgrounds will exhibit language, physical or cognitive problems later on. This is the nature of 'risk' as it is commonly used in research on the effects of developmental, social and environment factors on later outcomes for children (for example see Evans, 2004). Within this conception of risk it is not possible to say that particular factors *cause* a specific outcome. Rather, they are associated with the outcome at a later date and, thus, should be included in any measure of 'risk' if it is to have theoretical and predictive value.

The developmental factors identified in previous research as being associated with later outcomes (see section 1.7, p. 34) have been included in the measures of social, developmental and environmental factors in the present research. Therefore, these measures should have theoretical and predictive value for the language ability of the children who participated in this study. Specifically, it is expected that these measures will be correlated with language ability and that the language ability groups should differ with respect to the number and severity of risk factors reported.

In order to assess social, environmental and developmental factors, Sattler's (1992) parental interview protocol was used as the basis of the interview administered in the present research. Sattler's (1992) intake assessment interview for children is a well-known, respected and comprehensive tool that includes questions on perinatal, early cognitive and physical development, family background and behavioural information. The interview was modified to only include questions about the social, language and physical factors found to be associated with language and cognitive development. For example, the parental interview did not contain questions about the child's behaviour unless it was directly related to language or cognitive outcomes. The parental interview proforma is included in Appendix C. Parents were administered the interview by telephone.

The parental interview included questions on the parent's occupation, age and years of education. Also of interest were language risk indicators which included the number of books in the house, whether the child had been read to when young, and whether the child was currently read to and how often. Other language risk indicators were whether the child had normal language milestones and schooling history, had blood relatives with diagnoses of language/learning disorders and the number and severity of occurrences of otitis media with or without effusion.

In addition to questions on language risk indicators, physical risk indicators were assessed. These included questions on the child's perinatal history (prematurity, birth weight etc.), the amount of alcohol, other drugs and nicotine ingested by the mother during pregnancy, and the child's motor milestones and medical history.

The questions were arranged in subsections within the interview protocol. The scales for the physical risk index were coded from one to four, with one representing no risk, and four, high risk. For example, the coding for the child being premature was based on how many weeks early he or she was born, with one equalling not premature, and four being more than eight weeks premature. The items for the language risk index were coded from one to five using a similar rationale. For example, the question regarding how often the child was read to when young ranged from one, equalling being read to daily, to five, which meant the child had never been read to when he or she was young.

On dichotomous items, the presence of a risk factor was given a value of four or five (index dependent) and non-presence, a value of one, so that scoring was on the same range as other items. One item was scored on a scale from one to six. This was the code for number and severity of otitis media bouts a child may have experienced. The scale was developed to best represent categories resulting from a content analysis of parents' responses. A codebook with the coding scheme for each question is included in Appendix C.

After coding, the individual language and physical risk question scores were combined into language and physical risk indicators. Not all questions were included in the final indicators. This was due to some items having zero responses, for example, intellectual disability, and to some items contributing little to the reliability of the indicator. If an item did not contribute greatly to the reliability, but was considered theoretically important, it was retained in the index. Lists of the items included in the language and physical risk indices are included in two tables in Appendix C.

The language risk index contains 15 items with a Cronbach alpha reliability coefficient of .78 for the whole sample, and .88 for the matched groups sub-sample. The index has a possible range of 15 to 76, with higher scores indicating the child had experienced a greater number of potential risk factors for language problems. The actual ranges and the means and standard deviations for the whole and matched groups sub-samples are presented in Table 9.

The physical risk index contains 21 items and returns a Cronbach alpha reliability coefficient of .77 for the whole sample and .91 for the matched groups sub-sample. The possible range of the physical risk index is 21 to 84, with higher scores indicating the child had experienced a greater number of factors with the potential to affect physical and cognitive functioning. The ranges, means and standard deviations for the physical risk index for the whole and matched groups samples are presented in Table 9.

Table 9

Ranges, Means and Standard Deviations for the Language and Physical Risk Indices for the Whole and Matched Sub-Samples

Index	**Whole Sample *N* = 158**			**Matched Sub-Sample *N* = 30**		
	M	*SD*	Range	*M*	*SD*	Range
Language	26.85	10.87	15 – 63	27.67	12.52	15 – 63
Physical	27.83	6.64	21 – 75	28.57	10.83	21 – 75

In constructing the language and physical risk indices in the manner described above there was some concern that the distinction between biological and environmental factors and their predictive importance for language ability may be obscured. However, it is important to note that social, biological and environmental factors are often highly correlated and interactive and difficult to differentiate even in research designed to do so (Evans et al., 1999; Stromswold, 1998). A salient example of this is the childhood illness otitis media with or without effusion (OME). As discussed in section 1.7 (p. 36), recurrent bouts of this disease can impair hearing at critical periods in language development. Originally, OME was thought to contribute significantly to delayed and impaired language (Roberts et al., 1998). However, more recent research has shown that the early home environment is more important than the hearing loss associated with OME and that the home environment is also highly correlated with socio-economic factors (Roberts et al., 2002).

Thus, as research identifies interactive factors, separating the individual effect of each of these factors becomes increasingly difficult and questionable. Logically, it is only the combined effect of these early childhood factors that can be observed as being associated with problems later in childhood. Thus, the socio-economic, language and physical risk measures in the present study cannot be interpreted as being specifically biological or environmental in nature. The function of the indices in the present study is primarily as control variables that account for these interactive social, developmental and environmental factors that may affect language outcomes for children.

2.9 General Procedure

The testing procedure was similar at all schools. Testing equipment was set up in a room assigned by the principal at each school. Most rooms were relatively quiet and large, however, in some schools space was at a premium and this was reflected in the allocated room. Testing took place during school hours with the least disruption of the class' daily schedule as could be managed. Depending on the number of participants at the school, the class schedule and days lost due to sport, holidays etc., testing took from two days to five weeks to complete.

Each child was tested over two sessions. Each session took approximately one hour to complete, depending on the individual child. The children completed one session on one day and the remaining session on another day. This was to ensure that no child became fatigued or bored during testing. The children were thanked for participating and given a choice of some stickers and stamps to take home.

Three separate testing areas were set up. These consisted of a table for clinical tests including language and nonverbal IQ testing, and two separate computer testing areas. One half of the participants in each class began testing with the clinical tasks and the other half began with the computerised tasks. Table 10 shows the tasks in each session and the order in which they were administered. The order was reversed for every second child for each session type. Therefore, both session type and task/test order were counterbalanced across participants. Tasks were arranged so that those that took a long time, or were very repetitious, were followed by short tasks.

On the majority of occasions, there were two researchers, one conducting the mostly clinical session, and the other conducting the computerised tasks. This meant that two children could be tested during the same one-hour session. The principal researcher or a research assistant, both being registered psychologists, administered the clinical tests.

After testing at a school was completed, the principal researcher telephoned the consenting parent/guardian with feedback on their child's results. Feedback consisted of a child's performance relative to same age peers and published test norms on the CELF-3, the Standard Progressive Matrices, and digit span, and in reference to the class average for choice reaction time tests. Once feedback had been given, the parent was administered the structured developmental interview. All parents were thanked for their participation, and asked for permission to include a summary of their child's results in a school report to the principal and teacher. Four parents did not want their child's results disclosed to the school and these results were not included in any report.

Table 10

The Order of Tasks and Tests Across Participants

Session Type *Counterbalanced*	**Tests and Tasks** *Order Counterbalanced*
Mostly Clinical Session	Clinical Evaluation of Language Fundamentals-III
	Standard Progressive Matrices
	Nonword Repetition Task
	Arrow Task
	Auditory Repetition Task
Computerised Task Session	Latin Square Task
	Word Task
	Digit Span
	Spatial Span
	Figure Task
	N-Term Task

Parents of those children who were identified as having language or other problems were offered advice on avenues of assistance for their child and a written report/summary of testing. The schools received a summary report of individual and group results and the relevance of these results compared to same age peers. Any non-normal results were discussed in the context of the individual child's overall performance and in some cases, family history (with parental permission). For example, the three children who did not speak English as their first language had below average language test results, in some cases more than two standard deviations below the mean for expressive language. This was explained in the report in the context of the child's language history and the nature of the testing. A final report was presented to Education Queensland as part of the requirements of ethical approval. This report gives summary school analyses and a summary conclusion of the research.

Chapter 3

Correlational Relationships between Study Variables

The purpose of this chapter is to examine the bivariate relationships between the research variables and language ability. An associated question is whether language ability and nonverbal IQ are significantly linearly related as Leonard (1998) has suggested. This chapter also investigates a task-based issue. This is the question of whether tasks with a specific linguistic processing component have stronger relationships with language ability compared to tasks without such a requirement. This question arises from MacDonald and Christiansen's (2002) contention regarding verbal working memory tasks and their relationship to language tasks.

3.1 Hypotheses

Six hypotheses are examined. Firstly, it is hypothesised that the cognitive, perceptual and social/developmental variables will exhibit linear relationships with language ability. The majority of the research reviewed in Chapter 1 found significant differences between children with SLI and normally developing children for the cognitive and perceptual variables. It is hypothesised that these differences will translate into linear relationships for the non-clinical sample used in this study.

Secondly, a specific prediction is made regarding nonverbal IQ and language ability. It is hypothesised that these variables will be significantly related although not to the extent that language ability is related to variables with linguistic processing requirements.

Thirdly, it is hypothesised that the strongest bivariate correlations (linear relationships) for language ability will occur with tasks with a specific linguistic component and that these tasks will be correlated with each other. These tasks include Rapid Automatized Naming, the word memory scanning task and digit span. The fourth hypothesis is that language ability should exhibit a significant negative relationship with the language risk index as it measures factors known to be associated with child language.

The fifth hypothesis concerns whether there will be any difference in the strength of relationships between language ability and tasks that are presented aurally, or visually, or tasks that require a spoken or physical response. Previous research has found that children with SLI have difficulty performing many types of tasks (see Bishop, 1992 and Leonard, 1998 for reviews). Therefore, it is argued that task presentation and response modalities should not be associated with language ability in any specific pattern.

Finally, it is hypothesised that the pattern of correlations will be similar for both the whole sample and the matched sub-sample of 30 children. However, the relationships for the matched sub-sample will be stronger given the increase in variance expected due to the formation of specific ability groups.

3.2 Design and Data Screening

The whole sample and matched sub-sample data were screened for normality, and outliers beyond 2.5 *SD*s were modified in the manner suggested by Tabachnick and Fidell (2001, p.71). The values of extreme outliers were reduced to one greater than the highest score in the main body of data, which reduced the effect of extreme scores on analyses, but retained the position of the score in the dataset.

Approximately 4% and 8% of scores were modified in the whole and sub-samples respectively. The hypotheses were investigated via separate examinations of the bivariate correlations between language ability and the study variables for the whole sample (N = 158) and the matched sub-sample of language ability groups (N = 30). Due to the large number of bivariate calculations the alpha level was set to .01 to reduce the probability of Type I error. In addition, discussion of analyses is limited to correlations greater than .3, or those that explain greater than 10% of the variance.

3.3 Whole Sample Relationships

Bivariate correlations between major variables were calculated for the whole sample and are presented in Table 11. This table is divided into tasks with linguistic processing requirements (variables one to six), tasks without such requirements (variables seven to 14), and the social and developmental indicators (variables 15 to 18).

An examination of the correlation coefficients reveals that the language measures are, not surprisingly, highly correlated with each other. The relationships between receptive and expressive language measures and the total language score are large and significant (receptive language, r = .94, p < .0001; expressive language, r = .95, p < .0001). Therefore, the total language score will be used as the basis for comparisons between language ability and all other variables. The column containing the correlations with the total language score is shaded in Table 11 to aid the reader.

Table 11

Correlation Matrix for Major Study Variables for N = 158 Participants

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.RL	-																
2.EL	.80**	-															
3.TL	.94**	.95**	-														
4.RAN	-.23**	-.27**	-.27**	-													
5.Word	-.38**	-.36**	-.38**	.35**	-												
6.D/SP	.33**	.37**	.37**	-.19*	-.20*	-											
7.SPM	.56**	.46**	.53**	-.17*	-.22**	.30**	-										
8.Arrow	-.10	-.14	-.13	.30**	.39**	-.13	-.08	-									
9.Figure	-.26**	-.32**	-.30**	.21**	.70**	-.22**	-.12	.44**	-								
10.NRT	.46**	.53**	.52**	-.24**	-.30**	.26**	.26**	-.16*	-.29**	-							
11.S/SP	.26**	.25**	.27**	-.17*	-.23**	.16*	-.20*	-.20**	-.20*	.15	-						
12.N-T	.22**	.20**	.22**	-.15	-.02	.02	.21*	-.07	.03	.21*	.23**	-					
13.L/SQ	.37**	.30**	.36**	-.19*	-.29**	.13	.38**	-.16*	-.15	.19*	.14	.30**	-				
14.ART	.33**	.25**	.31**	-.36**	-.16	.17*	.20*	-.07	-.23**	.28**	.16	.14	.22**	-			
15.P/ED	.22**	.27**	.26**	.00	-.03	.15	.12	-.04	-.11	.14	.15	.07	.02	.10	-		
16.P/OC	.36**	.42**	.41**	-.11	-.18*	.18*	.23**	-.08	-.22**	.25**	.18*	.09	.17*	.25**	.62**	-	
17.L/R	-.46**	-.48**	-.50**	.21**	.27**	-.24**	-.24**	.12	.25**	-.34**	-.16*	-.05	-.22**	-.15	-.14	-.23**	-
18.P/R	-.25**	-.25**	-.26**	.12	.08	-.18*	-.22**	.01	.16*	-.15	-.16	-.14	-.24**	-.10	-.12	-.21**	.41**

**p* < .05, two-tailed, ***p* < .01, two tailed.

Note. RL = Receptive Language, EL = Expressive Language, TL = Total Language, RAN = Rapid Automatized Naming, D/SP = Digit Span, Word = Word memory scanning task; SPM = Standard Progressive Matrices, Arrow = Arrow task; Figure = Figure memory scanning task; NRT = Non-Word Repetition Task, S/SP = Spatial Span, N-T = N-Term, L/SQ = Latin Square, ART = Auditory Repetition Task, Y/ED = Years of Parental Education, P/OC = Parental Occupation Code, L/R = Language Risk Index, P/R = Physical Risk Index.

The highest correlations for the total language score (apart from the CELF-3 subscales) are with the Standard Progressive Matrices (r = .53, p < .01), nonword repetition task (r = .52, p < .01), language risk index (r = -.50, p < .01) and adult occupation (r_s = .41, p < .01). These variables account for between 20% and 30% of the variance in the total language score. Less variance (between 10% and 19%) of the total language score is explained by the word memory scanning task (r = -.38, p < .01), digit span (r = .37, p < .01), and the Latin Square task (r =. 36, p < .01).

The language risk index and the word memory scanning task are negatively related to language ability. High scores on the language risk index indicate a greater number of potential language developmental risks, which are related, as expected, to lower language scores. For the word memory scanning task, faster reaction times (lower scores) are related to higher language scores.

The total language score was correlated at an alpha of .05 with all other variables with the exception of the arrow task. However, no variable explained more than 10% of the variance in the total language score.

The tasks with linguistic processing requirements (other than the CELF-3 subscales) have significant relationships with language ability. The word memory scanning task and digit span each account for approximately 14% of the variance in language ability, while the Rapid Automatized Naming task accounts for only seven percent. It was hypothesised that these relationships would be stronger than correlations between language ability and tasks with no linguistic component. However, the strongest relationships with language are with nonverbal IQ, the language risk index and nonword repetition.

With regard to correlations between tasks with a specific linguistic processing requirement, the strongest relationships are mostly with other similar tasks. As an example, there was a significant correlation between Rapid Automatized Naming and the word memory scanning task (r = .35, p < .01), and between the nonword repetition task and the word memory scanning task (r = -.30, p < .01). However, none of the correlations explain more than 20% of the variance, and some language tasks are correlated with non-language based tasks. An example of this is the correlation between the word memory scanning task and the Latin Square task (r = -.29, p < .01).

There are minor differences in the strength of relationships between language ability and tasks that are predominantly visually presented compared to tasks that are predominantly presented aurally. In general, the strongest relationships with language ability occur with those tasks in which the child listens to the stimuli (nonword and auditory repetition tasks). However, there are also a number of significant relationships between visually presented tasks and language ability (see Table 11).

In addition, there are strong relationships between tasks with spoken output and language ability, for example, nonword repetition, digit span and Rapid Automatized Naming. A number of tasks requiring a physical response (button press) also exhibit strong relationships with language ability. Thus, although some differences are apparent for multimodal presentations and responses, there is no distinct pattern evident in the relationships other than the predominance of the nonword repetition task having the highest correlation with language ability.

Other noteworthy bivariate correlations in the whole sample occur between the word and figure memory scanning tasks (r = .70, p < .001) and between parental occupation code and years of parental education (r_s = .62, p < .001). The strong relationship between the memory scanning tasks probably represents similar task demands. The relationship between years of parental education and parental occupation code is expected given that greater years of education are generally required for professional occupations.

3.4 Matched Sub-Sample Relationships

Correlations between variables were also examined for the matched sub-sample of 30 children in the language ability groups. The bivariate correlations for study variables are presented in Table 12. As for Table 11, the tasks with linguistic processing requirements are variables one to six, the tasks without linguistic components are variables seven to 14, and the social and developmental variables are 15 to 18.

As hypothesised, the strength of the relationships between variables for the matched sub-sample is greater than those of the whole sample, due to the reduction in variation in the data. The pattern of results is similar, but not identical to those found in the whole sample data. However, the variables that have the strongest correlations with language are the same for both samples.

Table 12

Correlation Matrix for Major Study Variables for N = 30 Participants

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.RL	-																
2.EL	.92**	-															
3.TL	.98**	.98**	-														
4.RAN	-.25	-.29**	-.28	-													
5.Word	-.57**	-.58**	-.58**	.42**	-												
6.D/SP	.34	.34**	.34	-.20	-.21	-											
7.SPM	.78**	.71**	.77**	-.37*	-.44*	.34	-										
8.Arrow	-.35	-.34	-.35	.48**	.46*	-.21	-.45*	-									
9.Figure	-.53**	-.60**	-.57**	.19	.71**	-.46**	-.41*	.50**	-								
10.NRT	.69**	.76**	.74**	-.13	-.48**	.30	.58**	-.09	-.44**	-							
11.S/SP	.59**	.63**	.62**	-.47**	-.54**	.34	.62**	-.41*	-.37*	.43*	-						
12.N-T	.52**	.56**	.55**	-.29	-.35	.02	.70**	-.34	-.36	.45*	.51**	-					
13.L/SQ	.56**	.60**	.61**	-.16	-.38*	.24	.60**	-.00	-.39*	.41*	.42*	.70**	-				
14.ART	-.06	-.01	-.03	-.24	-.03	.04	-.02	.13	-.25	.00	.23	-.09	.13	-			
15.Y/ED	.49**	.49**	.50**	-.17	-.21	.39*	.37*	-.17	-.34	.37*	.15	.22	.21	-.35	-		
16.P/OC	.56**	.55**	.56**	-.17	-.39*	.38*	.46*	-.15	-.52**	.40*	.20	.31	.50**	-.20	.71**	-	
17.L/R	-.75**	-.74**	-.76**	-.47**	.40*	-.48**	-.61**	.26	.32	-.61**	-.69**	-.46*	-.58**	-.34	-.37*	-.42**	-
18.P/R	-.31	-.30**	-.31	-.16	.25	-.31	-.14	.18	.19	-.26	-.20	-.32	-.48**	-.31	-.14	-.24**	.52**

*$p < .05$, two-tailed, **$p < .01$, two tailed.

Note. RL = Receptive Language, EL = Expressive Language, TL = Total Language, RAN = Rapid Automatized Naming, D/SP = Digit Span, Word = Word memory scanning task; SPM = Standard Progressive Matrices, Arrow = Arrow task; Figure = Figure memory scanning task; NRT = Non-Word Repetition Task, S/SP = Spatial Span, N-T = N-Term, L/SQ = Latin Square, ART = Auditory Repetition Task, Y/ED = Years of Parental Education, P/OC = Parental Occupation Code, L/R = Language Risk Index, P/R = Physical Risk Index.

As with the overall sample, the correlations between the receptive and expressive language scores and the total language score (receptive language $r = .98$, $p < .0001$; expressive language $r = .98$, $p < .0001$) indicate a significant amount of shared variance. Therefore, the total language score will be used for all comparisons between study variables and language ability. In Table 12, the column containing the correlations for the total language score is shaded.

In the matched sub-sample analyses, three variables are correlated to a similar degree with language ability. The (marginally) strongest relationship for language ability (other than with expressive and receptive language scores) is with nonverbal intelligence ($r = .77$, $p < .0001$), as measured by the Standard Progressive Matrices. Although the magnitude of the relationship is greater, the finding is identical to that for the whole sample data. For the matched sub-sample data, nonverbal IQ and language ability, as measured by the total language score of the CELF-3, share 59% of the variance.

The relationship between the language risk index and the total language score ($r = -.76$, $p < .0001$) also accounts for approximately 59% of shared variance. As in the whole sample data, the negative correlation indicates that higher scores on the language risk index are related to lower total language scores on the CELF-3.

The third strongest relationship for the total language score is with the nonword repetition task ($r = .74$, $p < .0001$). High scores on the nonword repetition task are significantly related to high scores on the CELF-3 total language score.

Lesser relationships (between 25% and 40% of the bivariate variance explained) occur between the total language score and spatial span ($r = .62$, $p < .0001$), the Latin Square task ($r = .61$, $p < .001$), the word memory scanning task ($r = -.58$, $p < .001$), the N-Term task ($r = .55$, $p < .004$), the figure memory scanning task (r = -.57, p < .001), adult occupation (r = .56, p < .001), and years of parental education (r = .50, p < .005). These relationships are all in the expected directions.

With respect to differences between language ability and tasks presented verbally or visually, and tasks requiring spoken or physical output, results appear similar to those of the whole sample. That is, there is no distinct pattern of significant results favouring one presentation or response modality over another. However, the nonword repetition task is strongly correlated with language ability.

As in the whole sample data, there are other noteworthy correlations. The word and figure memory scanning tasks are strongly related due to the high degree of congruence in the tasks (r = .71, p < .0001). Similarly, the Latin Square and N-Term task are correlated significantly (r = .70, p < .001). The language risk index is strongly related to the nonword repetition task (r = .61, p < .0001), and the Standard Progressive Matrices is significantly correlated with the N-Term task (r = .70, p < .001), spatial span (r = .62, p < .001), the language risk index (r = .61, p < .001), and the Latin Square task (r = .60, p < .001).

There are some differences in the pattern of correlations between the whole sample data and the matched sub-sample data. These include the strength of the relationships, particularly between language ability, nonverbal IQ and the language risk index and the other variables. Another difference between the samples is that the auditory repetition task was significantly correlated with a number of other tasks in the whole sample data, but was not significantly related to any variable in the matched sub-sample data. This is contrary to the increase hypothesised in the correlations due to increased variability in the data, and to the trend for all other correlations to remain in a similar relational pattern, even though the coefficients have increased.

3.5 Correlational Results and the Implications for Study Hypotheses

Six hypotheses were investigated in this chapter. The first hypothesis was that the study variables would exhibit linear relationships with language ability. The correlational results support this hypothesis, however, this finding is qualified by the fact that results for the whole sample indicate only modest amounts of shared variance. It should also be noted that significant bivariate correlations do not rule out possible non-linear relationships. The correlational results for the matched sub-sample exhibit stronger relationships due to the reduction of variation in the data.

The second hypothesis predicted a significant relationship between language ability and nonverbal IQ, but that the degree of relationship would not be as great as between language ability and tasks with linguistic requirements. This hypothesis was partially supported. Nonverbal IQ and language ability are significantly correlated, however, the strength of the relationship was unexpected. Nonverbal IQ explains a larger amount of variance in language ability than any other variable, including those with linguistic processing requirements, in both data sets.

The third hypothesis predicted that tasks with linguistic processing requirements would be more strongly related to language ability than tasks without this requirement. The results of correlational analyses do not support this hypothesis. Firstly, the relationships exhibited between language ability and tasks with linguistic processing requirements are not as strong as other relationships with language ability. Secondly, the pattern of results differs for the whole and matched sub-samples, and tasks with no overt linguistic processing component have equally strong relationships with language ability. However, there are strong correlations between the tasks with linguistic processing components, suggesting analogous task demands. Similarly, capacity tasks with little overt linguistic processing components share variance with each other.

The hypothesis that the language risk index would be strongly negatively related to language ability is supported in both the whole and matched sub-sample analyses. Thus, the social, developmental and environmental factors hypothesised to have an effect on language ability, appear to have a qualitative effect over the range of abilities exhibited by this sample of children. This suggests that there should be significant differences between language ability groups for the number of potential risk indicators experienced. This hypothesis is investigated via analysis of variance in Chapter 4.

There is support for the hypothesis that there will be no differences in relationships between language ability and tasks with different modalities of presentation of stimuli, and required responses. There are no distinct patterns evident in the correlational results, with significant relationships between all types of tasks and language ability. Thus, in general, there is no real difference between tasks presented visually from those presented aurally, or between tasks requiring spoken output compared to those requiring a physical response. However, in both the whole and matched sub-samples, there is a strong significant relationship between language ability and the nonword repetition task, which is aurally presented and requires a spoken response.

The final hypothesis was that the pattern of results would be similar for the whole and matched sub-sample correlations, but that the matched sub-sample coefficients would be stronger, reflecting the increased variability in the data. The correlations are considerably stronger for the matched sub-sample data. However, the pattern of results, whilst similar overall, is considerably different for the auditory repetition task and its relationships to all other variables.

3.6 Discussion of Correlational Findings

Although support was provided for the hypothesis that variables found to be of importance in previous research have linear relationships with language ability, there are some interesting results evident in these correlational analyses. Firstly, the overall pattern of the correlational analyses indicates that many variables appear to be significantly related to each other, to language ability, to nonverbal intelligence and the language risk index. It could be argued that this may be indicative of more complex interrelationships than are explicable through examination of simple bivariate correlations. For example, the correlations between language ability and developmental risk indices and parental occupation are strong and significant, as are the correlations between nonverbal intelligence and these variables. Furthermore, the nonword repetition task has strong significant relationships with language ability, nonverbal intelligence, and the developmental and socio-economic variables. It is unique amongst the research variables because it is both aurally presented and requires a verbal response, perhaps making it the most 'language-like' of all tasks. The unexpectedly strong correlations for the nonword repetition task could provide evidence for both Baddeley's (1986) working memory model and its relationship to language, and for MacDonald and Christiansen's (2002) contention regarding the type of processing that verbal working memory is accessing. This issue will be examined in greater detail in Chapter 5.

The significant correlations between language ability, nonverbal intelligence and nonword repetition may arise from shared variance with socio-economic and developmental variables. For example, this may occur via mediational relationships, with socio-economic and developmental variables having an initial effect on cognitive and perceptual variables, which in turn affect language and perhaps nonverbal intelligence. This contention is examined within a number of theoretical frameworks by analysis of structural equation models in Chapter 5.

Another interesting finding is that the Standard Progressive Matrices, a measure of nonverbal intelligence, is most strongly related to language ability. In the correlational analyses, the relationship between nonverbal intelligence and language explains almost 30% of the shared variance in the whole sample data, and approximately 60% of the variance in the matched sub-sample data. In addition, nonverbal intelligence is also significantly related to many of the same study variables that have strong relationships with language ability.

The unexpected finding that nonverbal IQ has the strongest correlation with language ability lends support to Leonard's (1998) contention that language ability and nonverbal IQ are related, and that children with SLI may represent the lower ends of both distributions. However, the sample used in the present research is non-clinical. The relationship between nonverbal IQ and language ability may be particular to a non-clinical sample, as past research on children with SLI has generally shown no relationship between language ability and nonverbal IQ. This may be due to the diagnostic criteria used to select children for research participation in studies of SLI, or to the *specific* nature of the disorder. The relationship between nonverbal IQ and language ability in the present research may be particular to non-clinical samples, indicating different factors of importance for children with normal and impaired language.

There are two potential explanations for the difference between findings for nonverbal IQ and language in the present study and those found in quasi-experimental research on SLI. Firstly, SLI may be the result of entirely different developmental processes from those occurring in children with normal language functioning. If this were the case, normal language and SLI would represent bimodal, or overlapping, distributions across the range of language ability, with SLI being unrelated to nonverbal intelligence. Therefore, quasi-experimental studies comparing children diagnosed with SLI and normal children would find little or no differences between groups for nonverbal intelligence, because they would be comparing children from two separate populations with different relationships with nonverbal intelligence. Thus, the relationship found between nonverbal intelligence and language ability would only hold for a normal, non-clinical sample of children. The sample used in the present research does not include any children formally diagnosed with SLI, which may be the source of this unexpected result.

There are two reasons why this explanation seems unlikely. Firstly, although at the time of testing no child from the 158 participants in the whole sample had been formally diagnosed with SLI, 22 met the language criterion. Of those, 20 met the nonverbal intelligence criterion of a standard score of 85 or greater. All 22 children met the physical criterion, and all but two met the social and environmental criteria. These two children would fail other criteria mentioned above. Furthermore, eight children in the matched sub-sample of 30 children met all the criteria for a clinical diagnosis of SLI. Thus, it is a reasonable assumption that both the whole and matched sub-samples contain participants with very similar characteristics to children diagnosed with SLI, as well as children representing the normal range of language ability. The language scores of the children in the whole sample are relatively normally distributed with no indication of a bimodal distribution.

The second reason why the explanation that SLI occurs through completely different developmental processes is unlikely is that conceptualising what these processes may be is difficult. One possibility is that SLI may be the result of a failure to adequately assimilate the underlying code structure of language (Goldberg & Costa, 1981), and that this difficulty is not related to nonverbal functioning. This would account for the majority of previous research on SLI, which has found no significant differences between children with SLI and normally developing children in nonverbal intellectual functioning. However, it could be argued that the present pattern of results should reflect this, as 14% of the whole sample and 27% of the matched sub-sample contain children who meet the criteria for SLI.

There is another more likely explanation for the relationship found between language ability and nonverbal intelligence in the present research. This is that the assumption that research on SLI provides a unique opportunity to study issues of importance in language acquisition free from the effects of intellectual, social, physical and other problems is false. In fact, it might arise from a simple methodological artefact. Such an artefact would occur if children with SLI do not represent a separate distribution, but rather the lower end of the language ability continuum. If language ability is positively correlated with nonverbal intelligence, as was found in the present research, then children with SLI should also exhibit nonverbal intelligence scores at the lower end of a normal distribution. However, in quasi-experimental studies, the nonverbal IQ criterion for a diagnosis of SLI effectively matches any language impaired group of children to a group of children with normal language on nonverbal intelligence, such that no differences would be apparent. This commonly used criterion may effectively, but artificially, control for any linear relationship between nonverbal intelligence and language, by selectively eliminating between group variations in IQ through selection of participants. Thus, from this perspective SLI becomes a statistical and methodological artefact rather than a distinct disorder.

In addition, the pattern of correlations found in the present research is consistent with that found by Dyck et al. (in press), where the children in the study who scored poorly on language tasks were also more likely to score poorly on all other tasks, including nonverbal IQ. Thus, SLI, or other failures in normal language acquisition may, as Leonard (1998) suggests, represent the lower end of the language ability continuum and be related to similar levels of nonverbal functioning. This contention is examined in more detail through analysis of variance and covariance for language ability groups and performance on study variables, the results of which are detailed in Chapter 4.

Chapter 4

Language Ability Group Comparisons

The purpose of this chapter is to further explore and elucidate the relationships between cognitive, perceptual and social/developmental factors and language ability. The use of quasi-experimental and parametric techniques enables a closer comparison between the results of the present study and previous research, for example, highlighting any similarities and differences between a non-clinical sample of children with a wide range of language abilities, and children with SLI when compared with normally developing children.

The results obtained in the correlational analyses in Chapter 3 indicate that the strongest correlation for language ability, for both the whole and matched sub-samples, is with nonverbal IQ. In the matched sub-sample, nonverbal IQ and language ability share almost 60% of the variance. This finding is interesting given Leonard's (1998) contention that SLI may not be a distinct disorder, but may represent the lower end of the normal distributions of language and intelligence, and that nonverbal IQ is generally not investigated in SLI studies. In addition, the matched sub-sample correlational analyses specify a relationship between the language risk index and language ability that is almost as strong as that between nonverbal IQ and language ability. This relationship is expected given the theoretical foundation on which the index was constructed, which is that social, environmental and developmental factors have the potential to positively and negatively affect language ability.

The underlying premise of the present study is that research on SLI has demonstrated the importance of a number of factors for language acquisition. The focus of this chapter is to investigate whether these factors are important for language ability as a whole using similar quasi-experimental methodology to previous research on SLI. Quasi-experimental methodology is, and has been, very useful for elucidating differences between children with SLI and normally developing children. It was considered that the same type of methodology would be useful for elucidating differences between children with low, average and high language ability and to further investigate the hypothesis that the cognitive, perceptual and social/developmental factors would have linear relationships with language ability.

The results of the analyses in Chapter 3 present a potential problem for investigating differences between language ability groups. The strong relationships between the language risk index and language ability, and nonverbal IQ and language ability, particularly in the matched sub-sample, have implications for parametric analyses between groups. For example, these strong relationships, and thus shared variance, raise the question of whether any group differences found using analysis of variance would still exist if either nonverbal IQ or the language risk index were used as covariates. For example, if analysis of variance (ANOVA) indicated significant differences between low, average and high language ability groups for performance on the nonword repetition task, which is significantly correlated with both language ability and the language risk index, the result may be best explained by differences in language ability, or conversely, by differences in the level of potential language risk factors a child has been exposed to. Thus, any significant differences between language ability groups on performance on cognitive and perceptual tasks may be the result of differences in ability, or shared variance with nonverbal IQ or the language risk index.

A dilemma arises from attempting to answer this question. There is no way of knowing if group differences exist before using analysis of covariance (ANCOVA), unless analyses without covariates are undertaken first. As one increases the number of analyses conducted, the potential for Type I errors also increases. To address this, a Bonferroni type adjustment for potentially inflated Type I error (familywise) will be made for ANOVA analyses (Tabachnick & Fidell, 2001). Critical alpha for the Bonferroni calculations will be set at .001 for the dependent variable and .01 for each planned contrast. Thus, for a dependent variable with three planned contrasts between language ability groups, the Bonferroni corrected alpha probability level is .031. For ANCOVA analyses a more stringent probability level of .01 will be used to address potentially inflated Type I error from repeat analyses.

Related to the above dilemma is the fact that entering both covariates (nonverbal IQ and the language risk index) into the same analyses would reduce power through loss of degrees of freedom given the small sample size (for the matched sub-sample), and increase the probability of Type II error. Therefore, the covariates will be entered singly into analyses on a considered theoretical basis where possible. For example, it could be argued that tasks that have a linguistic processing component should be affected by the language risk index more than nonverbal IQ, and that nonverbal IQ should influence performance on tasks with nonverbal processing requirements.

4.1 Design and Hypotheses

As discussed in Chapter 2, section 2.6, three language ability groups were created in order to examine the relationships between language ability and the research variables. The differences between groups for each variable were planned to be examined using analysis of variance (ANOVA). The following hypotheses are based on the assumption that differences between groups on particular variables reflect the differential effect of that variable on language ability. However, the hypotheses do not account for the effect of highly correlated covariates. Therefore, in some analyses, the observed effect may be negated by the presence of nonverbal IQ or the language risk index in the analysis. The means and standard deviations for the low, average and high language ability groups for each test/task/measure are included in Tables 19 to 22 in Appendix D (pages 273 – 275).

Four hypotheses are investigated in this chapter; three concern between groups analyses and the fourth concerns within group, task condition effects for the memory task. Firstly, it is hypothesised that the nonverbal IQ scores of children meeting the language criterion for SLI (the low language ability group) will be generally lower than children with average or above average language ability. Secondly, it is expected that the cognitive, perceptual and social/developmental factors will be linearly related to language ability as suggested by the correlational analyses. Thirdly, and qualifying the second hypothesis, it is expected that the strongest effects will be for tasks with a specific linguistic component.

A final hypothesis is offered for the within subject analyses of the memory task. In general, any within group main effects found for task conditions in the study variables are to be expected due to task design and will constitute a manipulation check and not be reported unless of interest to the main study hypotheses. However, previous research has focussed on the within subjects results of the memory task (Gillam, Hoffman et al., 2002; Hoffman, 2001) as well as the between group effects. Therefore, the within subjects results of the memory task are reported after the between group analyses. It is hypothesised that the Hoffman (2001) task condition main effects and interactions will be replicated in the present research.

4.2 Description of the Language Ability Groups

Group data were screened, and found to comply with normality assumptions associated with analysis of variance and covariance. As outlined in Chapter 2, section 2.6, the groups do not differ on age $F(2,27) = 1.72$, $p = .199$. However, the groups differ significantly on receptive language $F(2,27) = 56.702$, $p < .0001$, partial $\eta^2 = .81$, expressive language $F(2,17) = 73.11$, $p < .0001$, partial $\eta^2 = .84$, and total language scores $F(2,27) = 86.79$, $p < .0001$, partial $\eta^2 = .86$. The means and *SD*s for each group for age, language and nonverbal IQ scores are presented in Table 5 in Chapter 2.

The language ability groups only contained 10 children. This was due to only 10 children scoring more than 1.25*SD* above the mean on the CELF-3, which limited the number of children in the high language ability group, and thus the numbers of matched children in the other groups. Small numbers of children in each group may limit the generalisability of the results that follow.

4.3 Analysis of Variance Results for Between Group Analyses

The cognitive, perceptual and social/developmental variables were entered into one-way or mixed analysis of variance with planned comparisons, which were the orthogonal set of comparisons possible for the three groups. Table 13 summarises the omnibus *F* results for each test/task/measure and presents the group planned comparison *F* results where the overall *F* is statistically significant. The means and standard deviations for the language ability groups for each test, task and condition are included in Tables 19 to 22 in Appendix D (pages 273 – 275).

The results of the analyses for the majority of tests and tasks indicate significant differences between language ability groups given the Bonferroni adjusted alpha level of .031. There is a relatively consistent pattern of difference evident in the analyses. The summary of results in Table 13 shows that in general, the low language ability group's performance, on all but two of the cognitive and perceptual tasks and both risk indices, is significantly poorer than both the average and high language ability groups' performance. In general there are no significant differences between the average and high language ability groups. The two tasks that do not result in this pattern of comparisons are nonverbal IQ and the auditory repetition task. The pattern for both of these tasks is for the low and average language ability groups to perform at a similar level, and to be significantly different from the high language ability group.

Table 13

Summary of Between Group Analysis of Variance Results for the Cognitive, Perceptual and Social/Developmental Variables

Test/Task/Measure (Dependent Variable)		*F*	*p*	Partial η^2
Nonverbal IQ (Standard Score)		24.40	.0001*	.64
Contrasts:	Low different from Average	3.72	.06	
	Low different from High	45.95	.001*	
	Average different from High	23.53	.001*	
RAN Task (Reaction Time in s)		1.22	.31	.08
Word Task (Reaction Time in ms)		4.71	.02*	.26
Contrasts:	Low different from Average	5.91	.02*	
	Low different from High	8.07	.008*	
	Average different from High	.17	.68	
Figure Task (Reaction Time in ms)		2.86	.07	.18
Arrow Task (Reaction Time in ms)		1.92	.17	.12
Nonword Repetition (Number Correct)		10.05	.001*	.43
Language Group x Number of Syllables		8.83	.001*	.40
Contrasts:	Low different from Average	5.44	.03*	
	Low different from High	20.09	.0001*	
	Average different from High	4.62	.04	
Digit Span (Number Correct)		.88	.43	.06
Spatial Span (Number Correct)		8.96	.001*	.40
Contrasts:	Low different from Average	7.20	.01*	
	Low different from High	17.44	.0001*	
	Average different from High	2.22	.15	

*$p < .031$ (Bonferroni corrected alpha)
Note. Contrast abbreviations are: Low = low language ability group, Average = average language ability group, High = high language ability group.

Table 13 continued.

Test/Task/Measure (Dependent Variable)		F	p	Partial η^2
N-Term Task (Number Correct)		7.31	.003*	.35
Contrasts:	Low different from Average	5.42	.03*	
	Low different from High	12.50	.002*	
	Average different from High	1.55	.23	
Latin Square Task (Number Correct)		8.63	.001*	.40
Contrasts:	Low different from Average	6.80	.02*	
	Low different from High	20.23	.0001*	
	Average different from High	3.39	.08	
Auditory Repetition Task (Number Correct)		5.18	.01*	.28
Contrasts:	Low different from Average	.25	.62	
	Low different from High	9.02	.006*	
	Average different from High	6.28	.02*	
Years of Parental Education		2.02	.15	.13
Parental Occupation		2.81	.08	.17
Language Risk (Index Score)		22.14	.0001*	.62
Contrasts:	Low different from Average	23.16	.0001*	
	Low different from High	40.78	.0001*	
	Average different from High	2.47	.13	
Physical Risk (Index Score)		4.68	.02*	.26
Contrasts:	Low different from Average	7.47	.01*	
	Low different from High	6.55	.02*	
	Average different from High	.03	.86	

*$p < .031$ (Bonferroni corrected alpha)

Note. Contrast abbreviations are: Low = low language ability group, Average = average language ability group, High = high language ability group.

Performance on a number of tasks did not differ across language ability groups. For example, the ANOVA results for three out of the four global processing speed tasks were not significant. Only performance on the word memory scanning task differed across groups. In addition, years of parental education and parental occupation were not significantly different between groups.

Only one interaction between language ability group and task condition was significant. This interaction occurred between the number of syllables in the nonwords in the nonword repetition task, and the language ability group. All three groups performed at a similar, near ceiling level for the one, two and three syllable nonwords. However, the low language ability group performed at a poorer level for the four syllable nonwords than either of the other two groups, as illustrated in Figure 8. Thus, the greater the number of syllables in the nonwords, the fewer phonemes the children in this group repeated correctly. The descriptive statistics for the language ability groups for this task are contained in Table 22 in Appendix D (p. 275).

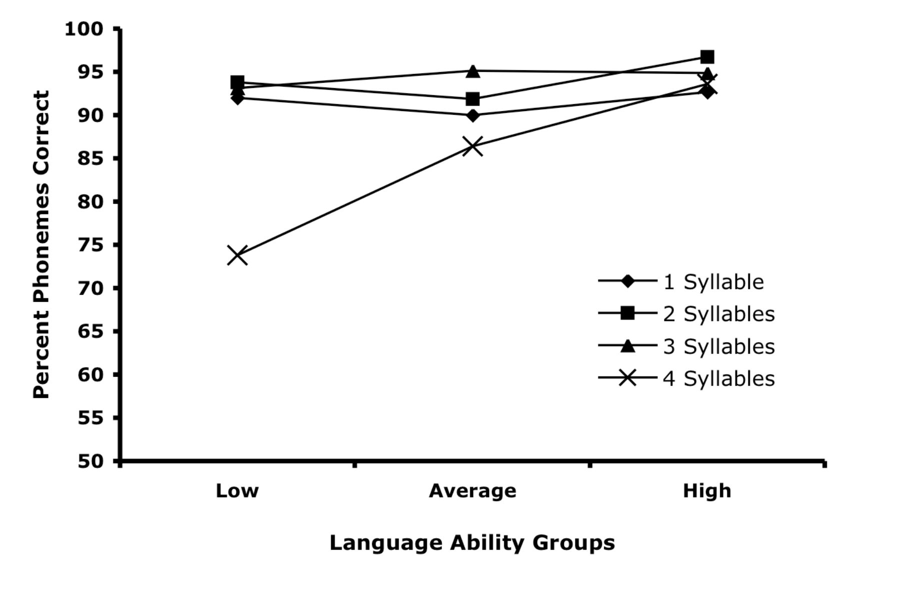

Figure 8. The interaction between language ability group and number of syllables in the nonwords in the nonword repetition task. The percentage of correctly repeated phonemes per nonword is graphed, as the number of possible correct phonemes differed with the number of syllables in the nonwords.

As stated previously, no other interactions between language ability group and task condition were significant and the results are not reported, with one exception: the auditory repetition task. The interaction between language ability group and interstimulus interval (ISI) on the auditory repetition task approaches significance $F(16,40) = 1.88$, $p = .054$, partial $\eta^2 = .43$, with a respectable amount of variance explained. The mean scores for each group across ISIs are presented in the graph in Figure 9, all means and standard deviations are contained in Table 21 in Appendix D (p. 274). The low and average language ability groups performed similarly. The performance of both of these groups is significantly different from the high language ability group's performance at discriminating tones at different ISIs, with one exception. The high language ability group's mean performance was poorer than the low or average language ability groups for the shortest ISI of 10ms.

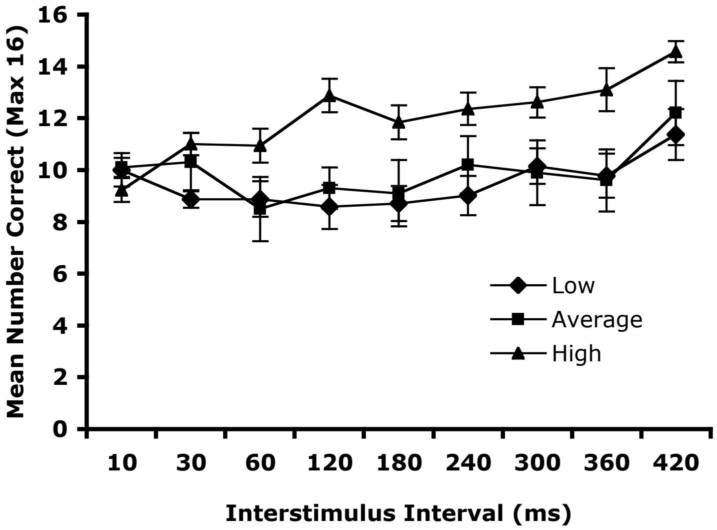

Figure 9. The mean (with standard error) number of correct tone discriminations at ISIs from 10ms to 420ms for the low, average and high language ability groups.

4.4 Analysis of Covariance Results for Between Group Analyses

As stated at the beginning of this chapter, due to the strength of the correlations for nonverbal IQ and the language risk index with language ability and other variables, these measures were included as covariates in analyses that proved significant through ANOVA. It was decided that the language risk index would be entered as a covariate into analyses of tasks that had a linguistic processing requirement and that nonverbal IQ would be used as a covariate for tasks that did not have this requirement.

Two tasks that did not have linguistic processing requirements, but were considered to be more likely to covary with the language risk index than nonverbal IQ were the nonword and auditory repetition tasks. This was due to the strength of the correlational results for the nonword repetition task with both language ability and language risk. The strongest correlations for the auditory repetition task appeared to be with language ability, the nonword repetition task and Rapid Automatized Naming. Therefore, the language risk index was used as a covariate in the analyses for the nonword and auditory repetition tasks.

Table 14 summarises the results of analysis of covariance (ANCOVA) for the cognitive and perceptual tasks for which the language ability groups' performances were significantly different. No further analyses were performed for the risk indices or nonverbal IQ.

As shown in Table 14, no significant differences between groups evident in the ANOVA results remained significant when the variance from either nonverbal IQ or the language risk index was removed from the equations.

Table 14

Summary Analysis of Covariance Results for Tasks which had Significant Differences in Performances Between Language Ability Groups

Test/Task/Measure (Covariate)	*F*	*p*	Partial η^2
Word Task (Language Risk Index)	1.66	.21	.11
Nonword Repetition (Language Risk Index)	2.18	.13	.14
Spatial Span (Nonverbal IQ)	2.01	.15	.13
N-Term Task (Nonverbal IQ)	2.04	.15	.16
Latin Square Task (Nonverbal IQ)	2.71	.09	.18
Auditory Repetition Task (Language Risk Index)	2.11	.14	.14

4.5 Analysis of Variance and Covariance Results for Within Group Analyses of the Memory Task

The within subject results for the memory task are reported in detail as they are directly relevant to previous research by Hoffman (2001). The means and *SD*s for the language ability groups for all task conditions are contained in Table 22 in Appendix D (p. 275). The data for the memory task were analysed using a mixed 2 (mode of response: verbal and spatial) x 3 (dual task: none, verbal and spatial) x 3 (language ability groups: low, average and high) ANOVA. The between subjects (language ability group) main effect is reported in Table 13. The within subject analysis resulted in two significant task condition main effects and one significant interaction. The first significant main effect is for the stimulus/response pairings (digit/verbal and spatial/motor).

This analysis resulted in a significantly different mean number of items recalled correctly $F(1,27) = 31.81$, $p = <.0001$, partial $\eta^2 = .54$, with all children recalling a greater number of digit than spatial stimuli as presented in Figure 10.

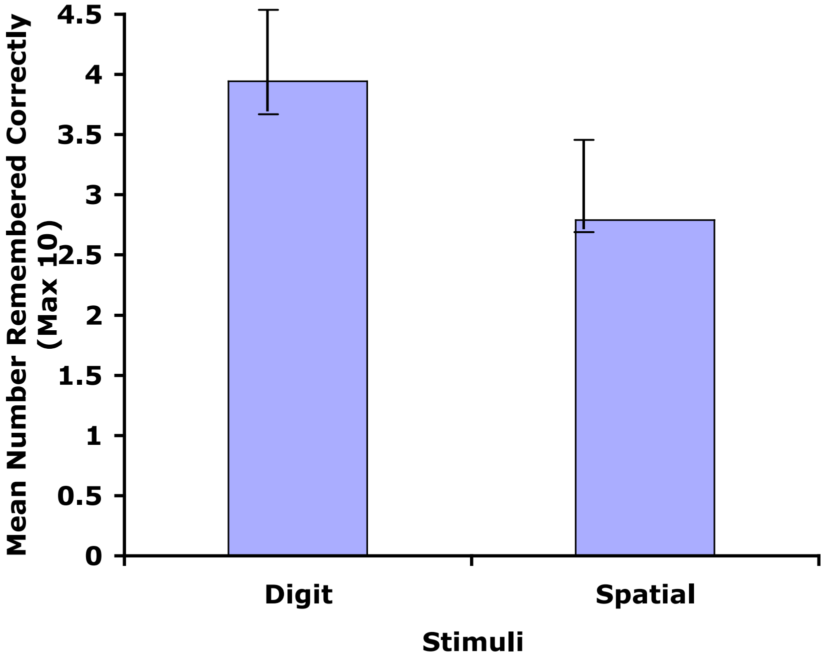

Figure 10. Mean (with standard error) number of items recalled correctly for type of stimuli in the memory task.

In addition to the main effect for type of stimulus/response, the results also indicated a significant main effect for the type of dual task (none, verbal, spatial) $F(2,54) = 54.14$, $p < .0001$, partial $\eta^2 = .67$. All children performed best when no dual task was required. In addition, performance was better when a verbal rather than a spatial dual task was required as presented graphically in Figure 11.

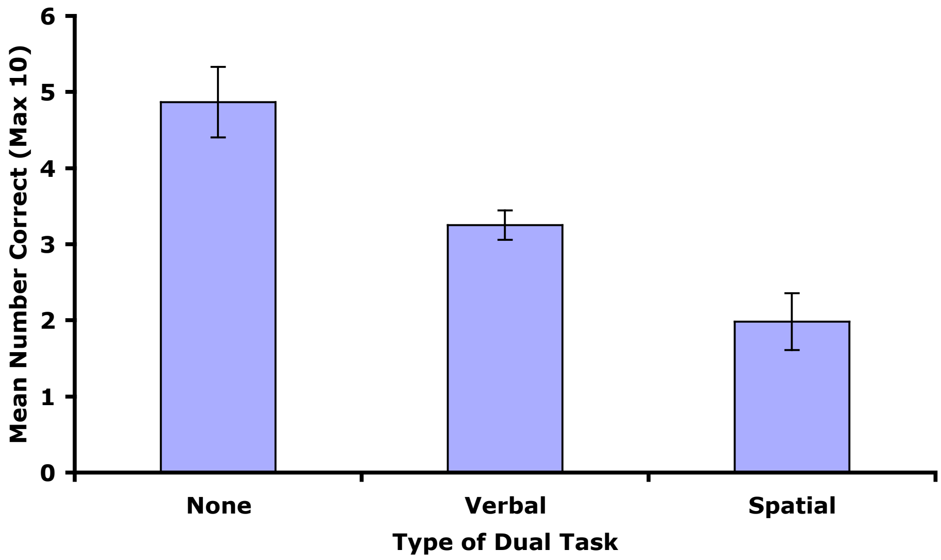

Figure 11. Mean (with standard error) number of all items remembered correctly for type of dual task for the memory task.

The only significant interaction for the memory task was the interaction between the type of stimulus/response required and the type of dual task $F(2,54) = 28.37$, $p < .001$, partial $\eta^2 = .51$. This result indicates a double dissociation occurred in which the greatest effect on performance was from a dual task that was the same response type as the primary task, although the presence of a dual task reduced performance across all conditions. For example, verbal responses were most affected by the verbal dual task, and spatial responses were most affected by the spatial dual task. This interaction is illustrated in Figure 12.

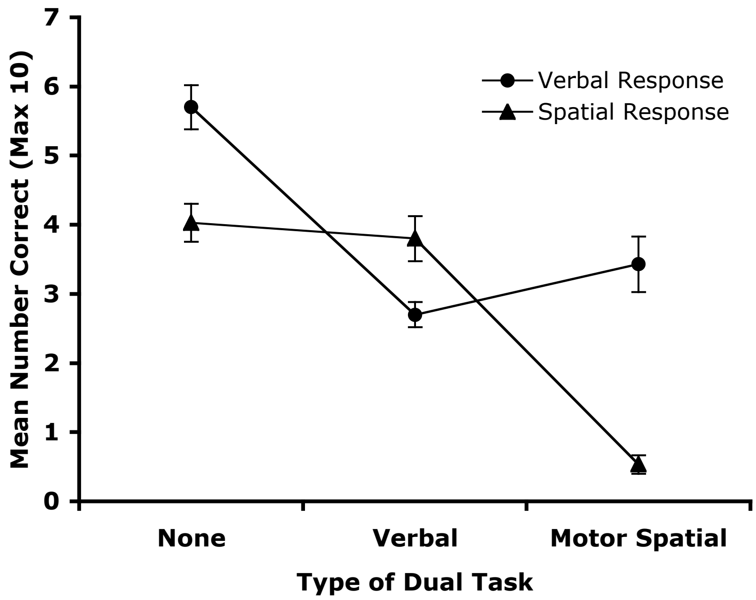

Figure 12. The interaction between type of stimulus/response and type of dual task for the memory task. The error bars indicate standard error of the mean.

The ANCOVA findings for the memory task are almost identical to the between group results. When the analyses for the memory task were repeated using nonverbal IQ as a covariate, none of the task condition or interaction results remained significant. There was however, a significant main effect for nonverbal IQ $F(2,26) = 8.73$, $p = .007$, partial $\eta^2 = .25$ indicating that a child’s nonverbal IQ plays a role in the performance of this task.

4.6 Discussion of Analyses and Hypotheses

The purpose of this chapter was to further explore and elucidate the relationships between cognitive, perceptual and social/developmental factors and language ability. Four hypotheses were investigated. The first of these, that children in the low language ability group would have lower nonverbal IQ scores than children in the average and high language ability groups was partially supported. The analysis of the nonverbal IQ data indicates significant differences between language ability groups. Specifically, the high language ability group's mean score on the Standard Progressive Matrices is significantly higher than both the average and low language ability groups' mean scores. There is no significant difference between the low and average language ability group's scores. The pattern of results between groups is similar to the research on children with SLI and normally developing children in which there are no differences between the groups on nonverbal IQ. Thus, it appears that nonverbal IQ may not have a consistent effect across the range of language ability, but may play a more significant role at the higher end. The size of the effect in this analysis is consistent with what would be expected from the correlational analyses in Chapter 3.

The results also indicate that the effect of nonverbal IQ is not confined to language ability. When the variance attributable to nonverbal IQ was removed from analyses of the spatial span, N-Term and Latin Square tasks, no significant differences in mean group performances remained. This suggests that the differences between the language ability groups in the ability to remember sequences of spatial stimuli and to solve visual/spatial problems of varying cognitive capacity requirements are explained by differences in nonverbal IQ.

The second hypothesis proposed linear relationships between study variables and language ability. A superficial examination of these results does indicate that most variables have linear relationships with language ability as hypothesised. However, the observation that many variables appear to be interrelated, and the subsequent inclusion of the language risk index and nonverbal IQ as covariates in analyses resulted in all significant differences between groups being negated. In addition, the results suggest that the relationship between nonverbal IQ and language may not be linear. Thus, the hypothesis that variables will exhibit linear relationships with language ability is only superficially supported.

The hypothesis that language ability groups would have significantly different performances, especially on tasks with a specific linguistic processing requirement, is not supported. The low language ability group is significantly different in performance on the word memory scanning task than the average and high language ability groups, but this was not sustained when the variance from the language risk index was removed. Therefore, the variance explained by the language risk factors accounts for the differences between the groups' mean reaction times on the word memory scanning task.

The other tasks with specific linguistic processing requirements did not exhibit any significant group effects. The Rapid Automatized Naming task, one of the optional subtests on the CELF-3, is claimed to be able to differentiate between language impaired children and normally developing children (Wiig, Zureich & Chan, 2000). In the present research, there appears to be little relationship between naming speed for well-learned colours and shapes, and a child's language ability. Similarly, the digit span task, which has a verbal response requirement, appeared to pose no significant problem for any of the child participants. Furthermore, an unexpected finding was that tasks that resulted in significant differences in performance between language ability groups had no specific linguistic processing requirements.

In relation to this unexpected result, there are two tasks with no overt linguistic processing requirements that may in fact contain aspects of language processing, or rely on similar types of abilities. These are the nonword repetition task and the auditory repetition task. Both are aurally presented, but only the nonword repetition task requires a spoken response. Moreover, the nonword repetition task may contain phonological processing requirements that are very similar to those in language processing tasks. The ANOVA results for both of these tasks indicated significant differences between groups, but interestingly, not the same pattern.

The results for the nonword repetition task indicate that the low language ability group had significantly poorer performance repeating nonwords than the high language ability group. This result was qualified by an interaction between the number of syllables in the nonword and language ability group. The low language ability group had difficulty repeating four syllable nonwords compared to their performance on one, two and three syllable nonwords. The average and high language ability groups performed at a similarly competent level regardless of the number of syllables in the nonword. This finding is similar to Vance's (2001) results in that children with language impairments had greater difficulty processing more complex nonwords.

When the language risk index is used as a covariate in the analysis of the nonword repetition task, no results remain significant. Participants' scores on this task are strongly correlated with language ability as demonstrated in correlational analyses in Chapter 3, however, the result does not hold when social, developmental and environmental factors are taken into account. From the results presented in this chapter and those of Chapter 3, it appears that these variables are complexly interrelated.

The other task for which the language risk index negated significant group differences is the auditory repetition task. This task is a measure of auditory temporal processing, that is, the ability to process sounds occurring rapidly in succession. The results of the ANOVA for this task indicate that the low and average language ability groups are significantly different from the high language ability group. The high language ability group returned a greater number of mean correct discrimination responses for the majority of interstimulus intervals.

This finding for the auditory repetition task is perplexing, as results from previous research suggest that differences would be expected between the low and average, or low and high language ability groups (Tallal & Piercy, 1973, 1974; Tallal, Stark & Mellits, 1985). In the present research, the performance of the low and average language ability groups was just above the level expected by chance except for the longest ISIs, whereas the high language ability group's score was greater than expected by chance for all ISIs. This suggests that the children in the low and average language ability groups may have found this task too difficult. Even so, that would not explain why children in the high language ability group did not find it as difficult. The difference between groups on this task does not remain significant when the language risk index is entered into analyses as a covariate. Thus, the differences between language ability groups at discrimination of sounds occurring rapidly appears to be more successfully explained by social, developmental and environmental factors that have the potential to adversely affect language ability. A potential explanation for this is that auditory temporal processing is a necessary part of speech perception, and therefore likely to be affected by the same interaction between hereditary, biological, physical and development processes that have observable effects on language development.

The final hypothesis concerned the results of the memory task analyses. It was hypothesised that the results of the present study would replicate Hoffman's

(2001) findings. This hypothesis was not supported by the results of analysis of variance. There was a significant group main effect for spatial span. Two task condition main effects and the interaction between stimulus/response and dual task modality were significant, as they were in previous research (Hale et al., 1996; Hoffman, 2001). However, the results differ from Hoffman's in that there were no significant language ability group by task condition interactions, and no enhancement of performance occurred with cross-modal interference.

Hoffman (2001) found that children with language impairments had poorer spatial memory spans than children with normally developing language. This result was replicated in the present study. There was a significant between group main effect for spatial span, but not for digit span. Hoffman argued that the results from the memory task indicated central executive impairments in children with SLI compared to normally developing children. This argument was based on differences in levels of interference from dual tasks apparent between groups. Interestingly, in the present research, no memory span task ANOVA results remain significant when the variance attributable to nonverbal IQ is removed. In addition, in the ANCOVA analyses there is a significant main effect for nonverbal IQ. This suggests that nonverbal IQ ability has a noteworthy effect on performance of this task, which may implicate explanations other than central executive functioning for differences between groups.

To summarise, research on SLI has illuminated a number of cognitive, social/developmental and perceptual factors that have the potential to affect normal language acquisition. The most prominent of these theoretical arguments have been investigated in the present research for their influence on the normal range of language exhibited in a non-clinical sample of children. From the analyses undertaken to this point, it is apparent that no single factor has separate, potentially causal effects on language, as previous quasi-experimental research on SLI would suggest. To date it appears that our understanding of the ways in which cognitive, perceptual and social/developmental factors affect language has been hampered by investigations focussing on small areas of the 'picture'. What is necessary is to look at the picture as a whole if we are to understand how the small areas fit and interrelate with each other.

Thus, it is argued that evidence from the strong and complex pattern of bivariate relationships exhibited between variables, and the differences in language ability group means, dependent on whether nonverbal intelligence and the language risk index are covariates or not, suggests a more coherent understanding of the data may emerge from multivariate relationships in structural models. To this end, four *a priori* models are examined in Chapter 5. These models structure relationships between variables based on evidence from previous research and on hypothesised relationships elucidated in Chapter 1.

Chapter 5

Structural Relationships between Major Research Variables and Language Ability

The focus of this chapter, and a main question of interest in the present research is; how are the major cognitive, perceptual and developmental variables, including nonverbal intelligence, interrelated and how do they relate to language ability? Limitations in the results of the correlational analyses in Chapter 3 and the group difference analyses in Chapter 4 suggest this is a question worth pursuing.

Results from the present research suggest that the argument that one factor is of prime importance in language acquisition, or in the aetiology of language impairment, is simplistic and unrealistic. Complex patterns of association are evident from analyses and discussions to this point. As Johnston (1991) argues, linking language acquisition to a single causal variable does not allow for understanding of the complex patterns that may exist. This chapter investigates the hypothesis that multivariate structural models, incorporating and testing theoretical accounts of the factors important for language ability, provide a clearer image of what the complex patterns for language ability may be.

In addition to this, structural models will be used to investigate MacDonald and Christiansen's (2002) claim that verbal working memory tasks are merely different types of language tasks, or that they share similar characteristics. If this is the case then estimations of the relationships between verbal working memory and language, and language and verbal working memory, should indicate a large amount of shared variance. The structural models will also provide evidence for or against Baddeley's (1986) tripartite model of working memory. Baddeley's model predicts that verbal working memory should be significantly related to language ability and that nonverbal working memory (or cognitive capacity) should be related to nonverbal IQ.

Thus, the purpose of this chapter is to examine models comprised of known and hypothesised relationships such as the global slowing and limited cognitive capacity hypotheses. A number of methodologies were considered for use in analysing the hypothesised relationships. Multiple regression techniques calculate the variance explained by a number of variables independent of other variables. However, this method does not allow one to hypothesise and quantify relationships other than between the independent and dependent variables, or for identification of moderating or mediating relationships between variables. Similarly, factor analysis allows for identification of variables that are structurally similar in the dataset, but does not provide for the analysis of more complex interrelationships. Path analysis allows specification of *a priori* relationships between any number of variables, but is limited by a lack of reliability as the relationships are based on a single measured variable only.

In comparison to path analysis, structural equation modelling (SEM), which is similar, is more robust and reliable. In SEM the latent variables, or the constructs of interest in the research, are considered to explain the variance in a *group* of measured, or observed variables. Thus, the models must be theoretically driven, as the latent variables are only as useful, reliable and valid as their underlying theoretical constructs, which the observed variables are supposedly measuring.

Another advantage of SEM is that the effects of different variables can be controlled through the exact specification of the model. For example, exogenous latent variables are those variables whose effects are considered to come 'first' in the model. Exogenous latent variables are always those on the far left of model diagrams, which 'read' from left to right. In structural equation models, the role of exogenous latent variables is analogous to the role of a covariate in ANCOVA. However, specifying variables as exogenous not only provides the advantage of controlling for their effect on all other variables, but also allows estimation of these effects in the overall specified model. Thus, a far more sophisticated and specific investigation of relationships can take place whilst controlling for the effect the exogenous variables have on other variables.

Many models also contain intermediate type latent variables that mediate the effects of the exogenous latent variables on other variables in the model and these intermediate variables then have an effect on the endogenous variable/s. Endogenous variables are those that occur 'last' in the model and take the far right position in the diagram. These are considered to be analogous to the dependent variable. There may be one or more endogenous variables in a model. Thus, one of the main advantages of SEM is being able to specifically nominate the types of relationships that the variables in the model have with one another, and to control for the effects of exogenous variables in particular.

There is one potential disadvantage of using SEM. The disadvantage is that larger sample sizes are required for the technique due to the greater number of measured variables increasing the number of parameters that have to be estimated, and placing corresponding restrictions on the degrees of freedom. Although this disadvantage has serious implications, the sample size of 158 was considered to be adequate for the analysis of the proposed models, based on the results of research experimenting with small sample sizes in SEM (Bentler & Yuan, 1999).

Therefore, a number of *a priori* structural models were tested using SEM techniques implemented in LISREL 8.54 (Jöreskog & Sörbom, 2003). The models comprise eight latent variables: developmental risk (D/RISK), socio-economic status (SES), verbal working memory (VWM), cognitive capacity (CAP), global processing speed (GPS), nonverbal intelligence (NVIQ), auditory temporal processing (ATP) and language ability (L/ABIL).

5.1 Model Development and Hypotheses

Four structural models were examined. The first, depicted in Figure 13, hypothesises direct relationships between seven exogenous latent variables and language ability, the endogenous variable. This model specifically proposes that nonverbal IQ, global processing speed, verbal working memory, cognitive capacity, auditory temporal processing, developmental risk and socio-economic status all have a direct effect on language ability (Campbell et al., 1997; Ellis Weismer et al., 1999; Evans & Maxwell, 1997; Evans, Maxwell & Hart, 1999; Gathercole & Baddeley, 1990; Kail, 1994; Law, 1992; Leonard, 1998; Tallal, 1980), and that they are not related. The direct effects model, due to its simplicity and because of the results from analyses in Chapters 3 and 4, is expected to provide the worst representation of the underlying structure in the data from the present sample. However, it will provide a comparison for more complex models, as it represents the disconnected state of current research.

The second model, illustrated in Figure 14, is a test of the hypothesis that slower processing speed underlies deficits found in children with SLI (Kail, 1994; Leonard, 1998), and thus, that global processing speed has implications for language ability as a whole. It is based on the hypothesis that global processing speed partially mediates the effects of exogenous social and developmental variables, and in turn, has a direct effect on verbal working memory, cognitive capacity, auditory temporal processing, nonverbal intelligence and language ability.

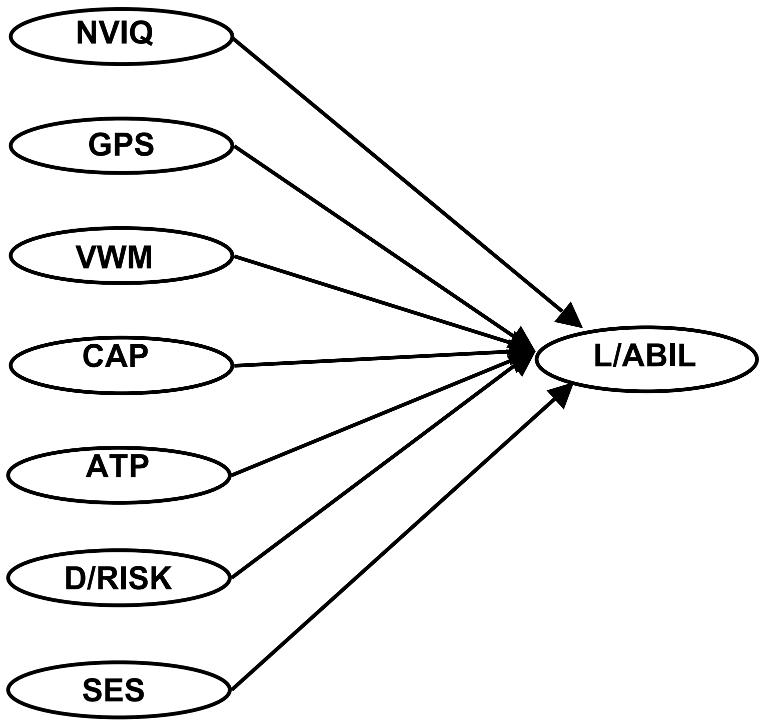

Figure 13. The conceptual diagram for the direct effects model.

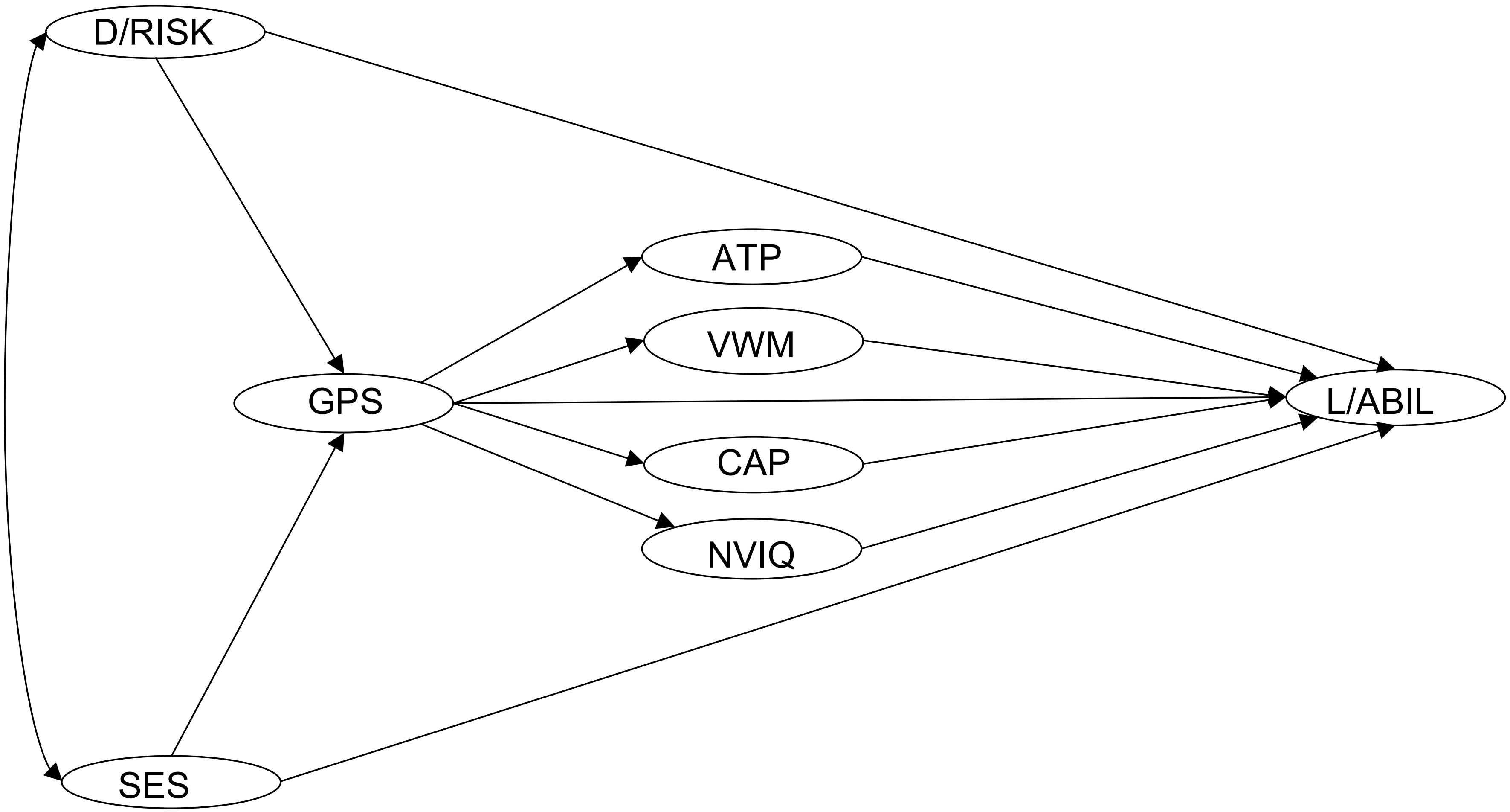

Figure 14. The conceptual diagram for the global processing speed hypothesis model.

It is hypothesised that social, developmental and environmental variables have both direct and mediated effects on language ability. However, the major mediating variable in this model is global processing speed. The prime contention of the model is that the social and developmental variables will be exogenous to the cognitive variable of processing speed, but that global processing speed will mediate their effects on all other cognitive and perceptual variables including language ability.

Many of the paths in this model are based on relationships previously identified and discussed in Chapter 1. For example, Fry and Hale (1996) proposed a developmental model in which processing speed had a direct effect on working memory, which in turn influenced fluid intelligence. However, most research on processing speed has concentrated on direct effects on various abilities such as language, working memory and intelligence (Jensen, 1993; Kail, 1994; Kail & Park, 1994; Vernon & Kantor, 1986). The direct paths from the social, developmental and environmental variables are also hypothesised based on previous research findings discussed in Chapter 1 (Evans & Maxwell, 1997; Evans, Maxwell & Hart, 1999; Law, 1992; Stromswold, 1998; Tomblin et al., 1997).

The global processing speed hypothesis model also allows for direct relationships from verbal working memory, cognitive capacity, auditory temporal processing and nonverbal intelligence to language ability. These relationships are based on previous research (see direct effects model), and results from Chapters 3 and 4, but this model hypothesises that verbal working memory, cognitive capacity, auditory temporal processing and nonverbal intelligence are directly affected by global processing speed. It is expected that the global processing speed hypothesis model will provide a reasonable fit to the data, based on relationships demonstrated in previous research.

The third model, illustrated in Figure 15, is based on research arguing that a limitation in cognitive capacity underlies SLI (Ellis Weismer, 1990; Montgomery, 2002), and therefore, in the present research, that cognitive capacity has implications for language ability as a whole. Like the global processing speed model, it is based on the hypothesis that cognitive capacity partially mediates the effects of the exogenous social and developmental variables.

The major difference between this model and the global processing speed model is that cognitive capacity, consisting of verbal and nonverbal components, is hypothesised to mediate the effects of the exogenous variables. Thus, the social and developmental variables will have direct effects on these cognitive variables. This model also allows for direct relationships between the social and developmental variables, auditory temporal processing, nonverbal intelligence and processing speed and language ability.

Once again, the paths in this model are based on research discussed in Chapter 1. For example, verbal working memory has been associated with language functioning (Campbell et al., 1997; Ellis Weismer er al., 1999; Gathercole & Baddeley, 1990), as has a more general capacity deficit (Ellis Weismer, 1998). In addition, working memory performance is associated with performance on tests of fluid intelligence (Fry & Hale, 1996) and improvements in information processing as children mature (Halford, 1994).

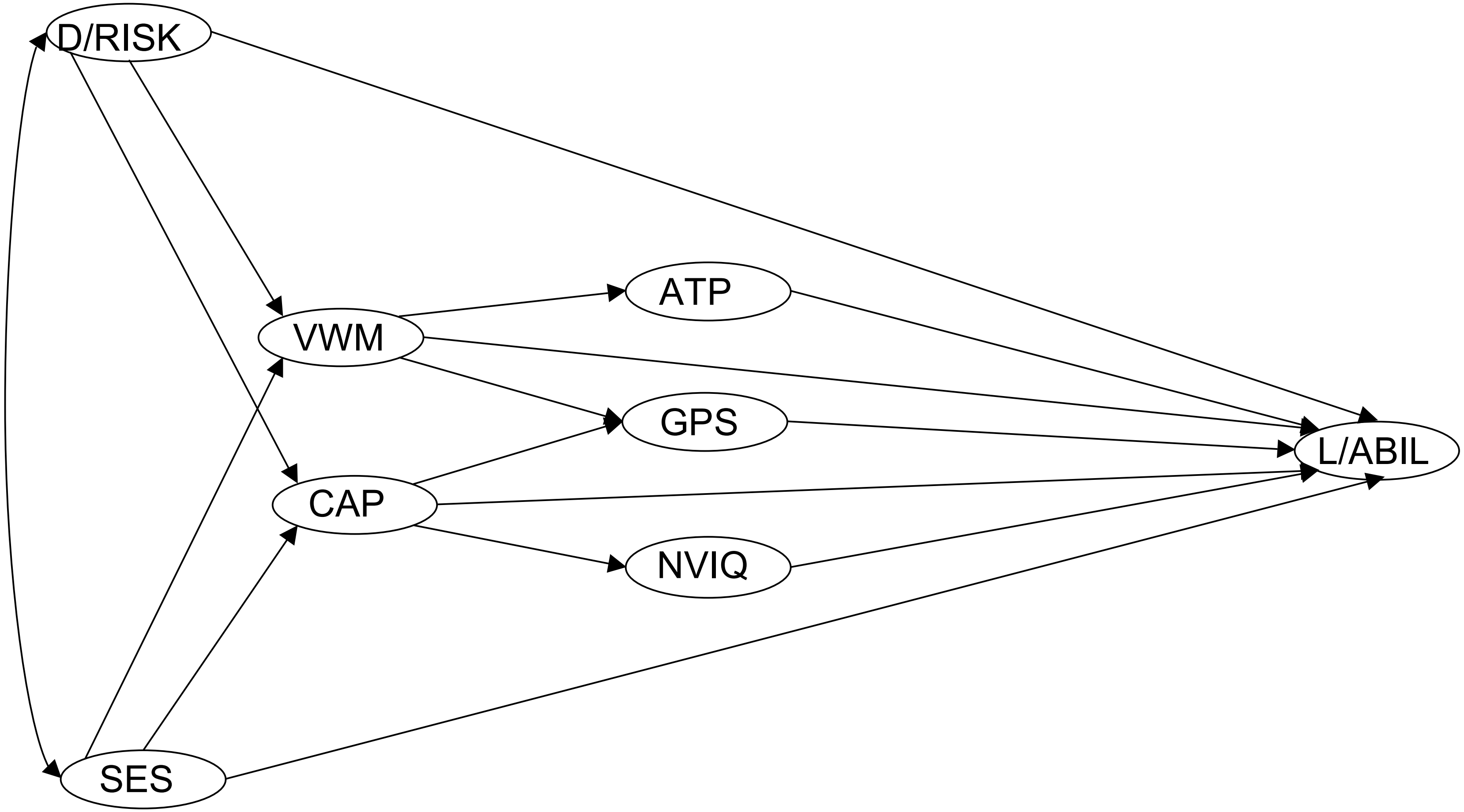

Figure 15. The conceptual diagram for the cognitive capacity hypothesis model.

In the cognitive capacity hypothesis model, cognitive capacity is divided into verbal working memory capacity and a nonverbal capacity measure. This is primarily based on Baddeley's (1986) model of working memory, and will provide a test of the model and the contention that verbal working memory tasks are just examples of language tasks (MacDonald & Christiansen, 2002). The verbal working memory and nonverbal capacity variables are hypothesised to have different effects on other latent variables. Verbal working memory capacity is hypothesised to have a direct effect on auditory temporal processing, global processing speed and language ability, reflecting their linguistic relatedness.

The nonverbal capacity variable is hypothesised to have a direct effect on global processing speed, language ability and nonverbal intelligence. Global processing speed is included here because the latent variable in this model contains measured variables with both linguistic and non-linguistic processing requirements, and thus should be affected by both capacity variables.

Like the global processing speed model, this model is also expected to provide a reasonable fit to the data, based on the most recent research evidence and theoretical debate. As stated, it will also provide a test of the domain-specific working memory hypothesis predicted by Baddeley's (1986) working memory model, and the contention that the strong relationship between cognitive capacity and language ability is largely an artefact of the type of tasks used to measure both language, and verbal working memory especially (MacDonald & Christiansen, 2002).

Evidence against both Baddeley's and MacDonald & Christiansen's arguments would occur if both the direct paths between verbal working memory and nonverbal cognitive capacity and language ability were significant. This pattern of results would reflect a non domain-specific processing relationship between cognitive capacity and language ability and pose some difficulties for Baddeley's model, and MacDonald and Christiansen's (2002) argument that high correlations between verbal working memory and language are due to the similarity of task demands and not to specific processing ability or capacity differences.

However, if model parameter estimations show that only verbal working memory has a direct relationship with language ability, this could arise from a relationship such as that suggested by Baddeley's working memory model. However, such a relationship could also indicate that verbal working memory tasks share similar demands to language tasks as MacDonald and Christiansen suggest. A model reversing the relationship between language ability and verbal working memory by specifying a direct path *from* language ability *to* verbal working memory and the other cognitive and perceptual variables would clarify this. For example, a non-significant reverse relationship between verbal working memory and language ability would provide support for Baddeley's model. However, a significant parameter estimate for a path from language ability *to* verbal working memory would indicate support for MacDonald and Christiansen's contention.

Thus, in the event of a significant domain-specific relationship between verbal working memory and language ability in the cognitive capacity hypothesis model, a fourth model will be analysed. This model examines the proposition that language ability mediates the effects of the exogenous social and developmental variables, and in turn has a direct effect on nonverbal IQ, auditory temporal processing, global processing speed, verbal working memory, and nonverbal capacity. The conceptual diagram for this model is illustrated in Figure 16. It is proposed that in the event of a domain-specific relationship between verbal working memory and language that this model, which reverses the relationship, will provide a test of the hypothesis that verbal working memory tasks are just special types of language tasks as suggested by MacDonald and Christiansen (2002). At the very least, significant relationships *from* language to the cognitive and perceptual variables will indicate that trying to isolate language from experimental or other tasks may be difficult or impossible.

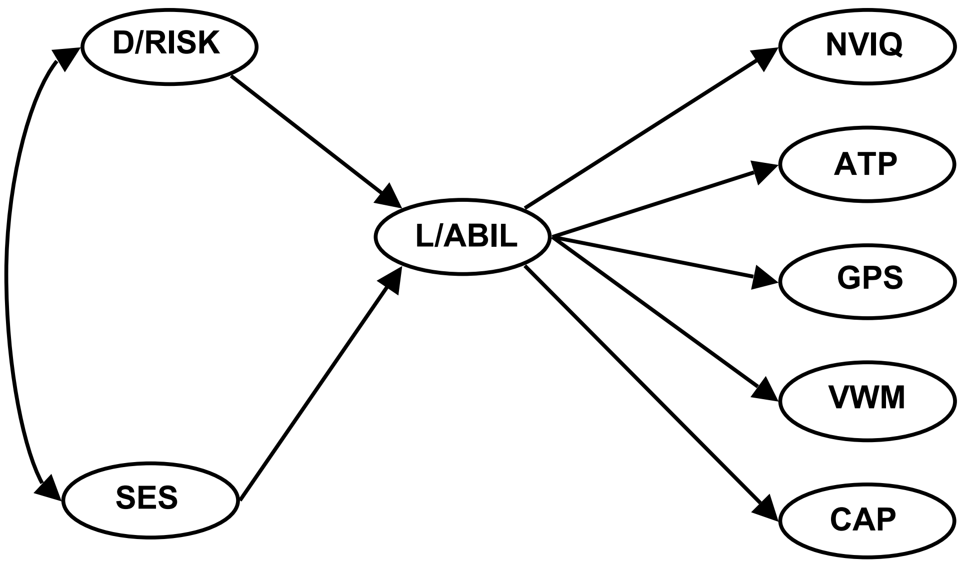

Figure 16. The conceptual diagram for the effects of language model.

5.2 Data Screening

Data for the observed variables were screened for normality and the value of outliers beyond 2.5 *SD*s from the mean were reduced to take the next value after the highest score value in the main body of data for the particular variable. This reduces the effect of extreme scores on analyses, but maintains the position of the score in the dataset (Tabachnick & Fidell, 2001). Two variables failed further stringent multivariate normality tests on the LISREL pre-processor PRELIS (Jöreskog & Sörbom, 2003b), although they had met normality criteria for ANOVA. These were the language and physical risk indices. Initial analyses run without transforming these variables failed to converge on a solution. Therefore, square root transformations were carried out on these two variables based on their distribution (Tabachnick & Fidell, 2001). Interpretation of the transformed variables is not affected, as the measures only reflect a relative level of risk, not an absolute measure. Thus, these variables are referred to as language and physical risk indices, however, for all LISREL analyses, the measures used are the square root transformations.

An analysis of missing data was undertaken which indicated that less than 5% of data were missing and that these data were randomly distributed. Due to the concern of maximising the sample for structural modelling purposes, missing data were replaced using the estimation method (EM) procedure on the Statistical Package for the Social Sciences (Version 11.0).

Once data were screened as outlined above, the covariance matrix was computed by PRELIS, saved in a file, and used in all subsequent LISREL analyses. Thus, all model tests use maximum likelihood (ML) estimation and are based on the covariance matrix, which is presented in Table 23 in Appendix D.

5.3 Model Analyses

A sequential approach to model specification and identification was used (Kelloway, 1998). Firstly, the measurement model was analysed using confirmatory factor analysis to ensure identification and reliability of observed indicators. Once the measurement model was assessed for reasonable fit, the four structural models, as outlined above, were considered. The direct effects model converged successfully with results reported below. Unfortunately, neither the global processing speed hypothesis, nor cognitive capacity hypothesis model would converge to a solution in the form presented in Figures 14 and 15.

An examination of the LISREL output from the attempted analysis of these models indicated a problem arising from including both the mediated and direct paths from developmental risk and socio-economic status. This resulted in a case of linear dependency or redundancy where language ability was perfectly, or 'over' predicted by the combination of direct and indirect paths. Diagnostic output provided by LISREL indicated the direct paths from developmental risk and socio-economic status did not represent strong relationships with language ability, whereas, the mediated paths through the other variables (global processing speed, verbal working memory and cognitive capacity in their respective models) did. Thus, the hypothesis that language would be both directly and indirectly affected by socio-economic status and language and physical risk indicators was not supported. In order to rectify the problem and enable model identification and convergence, the direct paths from developmental risk and socio-economic status were removed. The diagrams for the adjusted models, including parameter estimations, are presented with the model results in the following section. Table 16 (presented after the model analysis results) provides a comparison of fit indices for each model, including the measurement model as a baseline.

A selection of indices representing different aspects of model fit is presented as an aid to determining the best fitting model. That is, an indication of how well the *a priori* model reproduces the data covariance matrix (Kelloway, 1998). These include Chi-square and Normed Chi-square (χ^2 and χ^2 /df), as indicators of model fit. For a good model fit, Chi-square should be non-significant (i.e. $p > .05$) and Normed Chi-Square should be within the range 1.0 – 3.0, with values close to one indicating good fit (Kelloway, 1998).

A number of indices of absolute fit are also presented. These indicate how well the model replicates the covariance matrix and include the Root Mean-Square Error of Approximation (RMSEA), and the Goodness-of-Fit Index (GFI). Values of less than .05 for the RMSEA, and values of greater than .95 for the GFI indicate good fit, however, values between .90 and .95 for the GFI may also indicate satisfactory fit (Kelloway, 1998). In addition, two measures of comparative fit are included. Comparative, or incremental fit indices are useful for comparing two or more models to identify the best fit to the data (Kelloway, 1998). Those included are the Tucker-Lewis Index (called the Non-Normed Fit Index on LISREL, the version that will be reported here) and the Comparitive Fit Index (CFI). For both the Non-Normed Fit Index (NNFI) and the CFI, values greater than .95 indicate good fit, although values between .90 and .95 may indicate satisfactory fit. A measure of model parsimony is also included. This is the Model Consistent Akaike Information Criterion (Model CAIC). The most parsimonious model will result in the smallest value for the Model CAIC.

A comparison of fit indices between models helps determine the best fitting model. However, it is also important to examine the parameter estimates in the structural model. Parameter estimates are interpreted in the same way that correlation coefficients are, with values occurring between –1 and +1. Like correlation coefficients, the squared parameter estimate of the path between two variables gives the amount of variance explained by the specified relationship between the two variables. In addition, the endogenous variable, which in most of the following models is language ability, is reported with an error or residual term. This is the amount of variance not explained by the specified paths in the model. The formula for calculating the amount of variance explained for the endogenous latent variable is 1- error.

5.3.1 The Measurement Model

The measurement model is the estimation of the relationships between the observed/measured variables and the latent constructs that are proposed to explain them. The latent variables consist of between two and six observed/measured variables. The measurement model provides an acceptable fit to the data $\chi^2(377) = 416.89$, $p = .076$; RMSEA = .026. Standardised parameter estimates are all statistically significant at $p < .01$ and are presented in Table 15.

Estimates of construct reliability for the latent variables were computed using the parameter estimates and error terms from the measurement model using the following equation,

$$\rho_\eta = \frac{\left(\sum \lambda_i\right)^2}{\left(\sum \lambda_i\right)^2 + \sum \varepsilon_i}$$

where ρ_η is the measure of construct reliability, λ_i is the standardised loading for each observed variable and ε_i is the associated error variance for each observed variable (Fornell & Larcker, 1981). The reliability coefficients are reported for each latent variable in Table 15.

Table 15.

The Standardised Parameter Estimates and Reliability Coefficients for Latent Variables in the Measurement Model

Measured Variables N=158	Latent Variables LABIL	NVIQ	GPS	VWM	CAP	ATP	DRISK	SES
CELF-3:								
Sent/Struct	.56**							
Conc/Dir	.71**							
Word/Class	.77**							
Word/Struct	.75**							
Form/Sents	.83**							
Recall/Sents	.81**							
Reliability	*.88*							
SPM:								
Set A		.48**						
Set B		.79**						
Set C		.71**						
Set D		.81**						
Set E		.53**						
Reliability		*.80*						
RAN			.40**					
Arrow			.51**					
Words			.86**					
Figures			.79**					
Reliability			*.75*					
NRT				.60**				
Digit Span				.43**				
Reliability				*.42*				
Spatial Span					.39**			
N-Term					.46**			
L/Square					.61**			
Reliability					*.51*			
ATP:								
ISI 120						.72**		
ISI 180						.75**		
ISI 240						.80**		
ISI 300						.83**		
ISI 360						.79**		
Reliability						*.89*		
Lang Risk							.88**	
Phys Risk							.44**	
Reliability							*.63*	
Parent Age								.36**
Parent Ed								.65**
Occupation								.96**
Reliability								*.72*

** $p < .01$, two-tailed.
Note. Abbreviations are: SPM = Standard Progressive Matrices, RAN = Rapid Automatized Naming, NRT= Nonword repetition task, ATP = Auditory temporal processing, Ed = Education.

As the figures in Table 15 indicate, reliability coefficients range from .89 to .42, with the lowest coefficients associated with latent variables with fewer measured variables. Whilst the lower coefficients do not indicate ideal reliability for these variables, all parameter estimates were significant at the $p < .01$ level. In the interests of parsimony, the five of the nine discrimination measures with the greatest parameter estimates were chosen to represent the latent variable auditory temporal processing.

5.3.2 The Direct Effects Model

The first model, a test of the direct effects of the latent variables (nonverbal IQ, processing speed, verbal working memory, cognitive capacity, auditory temporal processing, developmental risk and socio-economic status) on language ability, gives a poor fit to the data $\chi^2(398) = 669.92$, $p < .0001$; RMSEA = .07, compared to the measurement model. The model, with standardised estimated parameters is illustrated in Figure 17.

Three of the direct paths from the exogenous variables to language ability are not significant. These are processing speed (β =-.07), cognitive capacity (β =.15), and auditory temporal processing (β = .03). The four significant paths to language ability are from nonverbal IQ ($\beta = .25$, $p < .01$), verbal working memory ($\beta = .57$, $p < .01$), developmental risk ($\beta = -.40$, $p < .01$), and socioeconomic status ($\beta = .26$, $p < .01$).

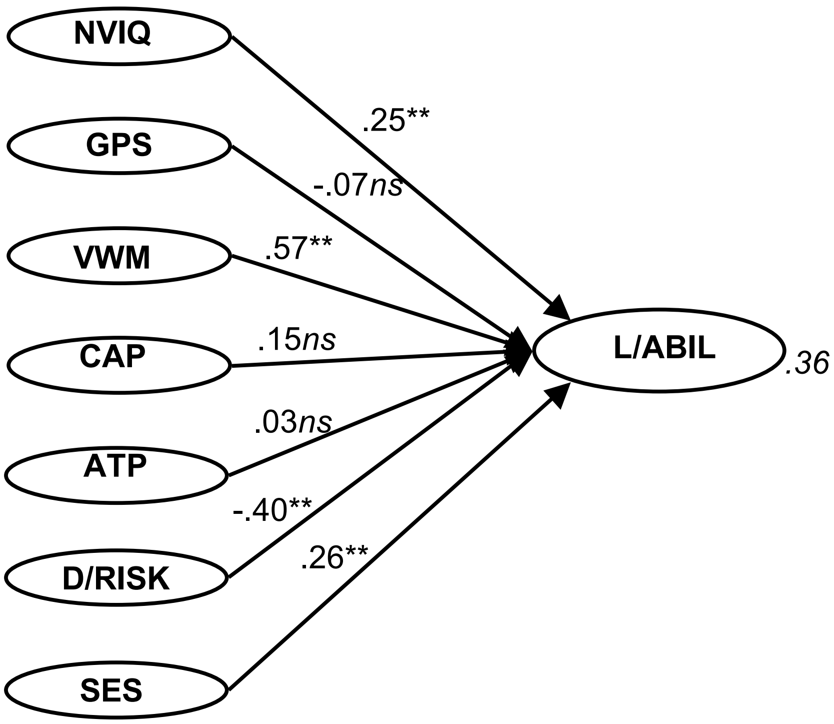

Figure 17. The direct effects model structural equation model with parameter estimations. ** *p* < .05, **p* < .01, *ns* = non-significant.

The residual term, or the error estimate, in italics beside the language ability latent variable, indicates that this model explains 64% (1 – error) of the variance in language ability. However, as stated previously, it gives a poor representation of the underlying data. This model was not expected to provide a good fit to the data as it is no more structured than looking at isolated direct relationships between individual variables and language ability. This is reflected in the parameter estimates, which are similar to the bivariate correlations obtained for the whole sample, shown in Table 11 in Chapter 3. However, it does represent the current state of language research in which single variables are investigated with a view to providing understanding of both language acquisition and language impairment.

5.3.3 The Global Processing Speed Hypothesis Model

The second model, a test of the global processing speed hypothesis, also provides a poor fit to the data compared to the measurement model, but the fit is better than the test of direct effects $\chi^2(393) = 543.42$, $p = .0001$; RMSEA = .05. The model is illustrated, with completely standardised parameter estimates, in Figure 18.

As can be seen from the model illustration, the correlation between socio-economic status and developmental risk is significant (β =-.35*, $p < .05$)*. Of the paths from these two exogenous variables, the path between developmental risk and processing speed is significant (β = .53, $p < .05$), whilst the path between socio-economic status and processing speed is not (β = -.17, *ns*).

Of the paths from global processing speed to the other endogenous latent variables, those to cognitive capacity (β = -.66, $p < .05$), verbal working memory (β = -.79, $p < .05$), auditory temporal processing (β = -.35, $p < .05$), and nonverbal IQ (β = -.48, $p < .05$) are all statistically significant. The path from processing speed to language ability (β = .52, *ns*) is surprisingly non-significant given its magnitude in comparison to the other statistically significant parameters. This may be because the direct path to language ability is redundant given the number of other mediated paths from processing speed through other variables. The only significant parameter estimate from any latent variable to language ability is nonverbal IQ (β = .19, $p < .05$), although the path estimate explains only 3.6% of the variance in language ability in this model.

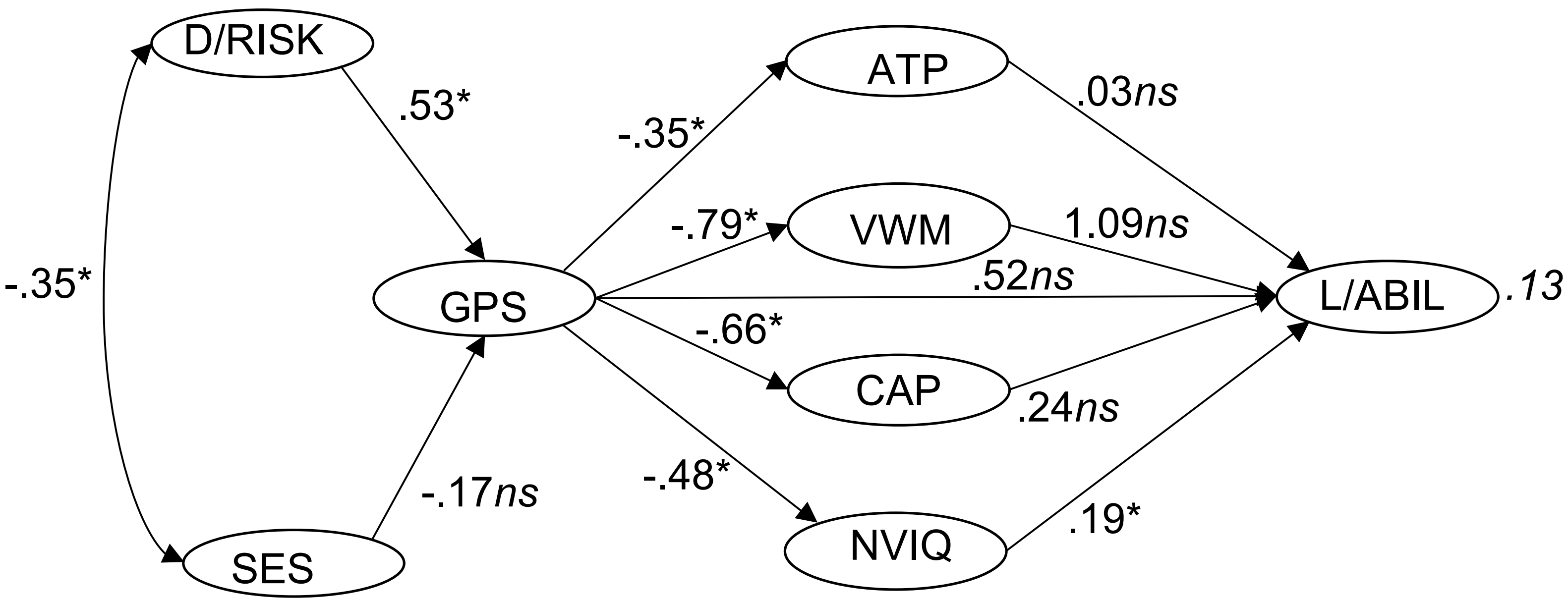

Figure 18. The global processing speed hypothesis structural model with parameter estimates. * $p < .05$, ns = non-significant.

The path from verbal working memory to language ability (β = 1.09, *ns*) is out of range. Completely standardised parameter estimates are constrained to be within the range from –1 to +1. Out-of-range and nonsensical estimates may be the result of a number of problems. Firstly, out-of-range estimates may represent linear dependencies or redundancies between variables. They may also be the result of model misspecification. For example, the inclusion of both direct and mediated paths in a model may 'over-estimate' the relationship along one of the paths.

In addition to out-of-range estimates, the overall fit of this model is poor, although it appears to explain 87% of the variance in language ability. LISREL provides modification indices as a suggestion for how model specification and model fit may be improved. These were examined, not with the view of re-specifying the model, but for clues to how the model was misspecified. The indices recommend the addition of paths from developmental risk and socio-economic status to verbal working memory, cognitive capacity and language ability. Also included was a path from cognitive capacity to nonverbal intelligence. Allowing the error variance between verbal working memory and language ability to covary was also suggested, and would result in a significant benefit to the fit of the model. Interestingly, the indices also suggest adding a number of paths *from* language ability *to* auditory temporal processing, nonverbal IQ and global processing speed.

Given the out-of-range estimate between verbal working memory and language ability and the modification indices outlined above, it is likely that this model is fatally flawed in its specification. That is, it represents the underlying structure in the covariance matrix very poorly in comparison to the measurement model. Apart from the paths *from* language ability, changing the processing speed hypothesis model in the manner suggested by the modification indices provided by

LISREL would result in a model very similar in intent to the cognitive capacity hypothesis model.

5.3.4 The Cognitive Capacity Hypothesis Model.

The model testing the cognitive capacity hypothesis provides an acceptable fit to the data $\chi^2(391) = 434.18$, $p = .06$; RMSEA = .03, explaining 88% of the variance in language ability. The cognitive capacity model is illustrated in Figure 19, including completely standardised parameter estimations.

An examination of the model shows that the exogenous variables socio-economic status and developmental risk share approximately 16% of the variance explained between them ($\beta = -.42$, $p < .01$). The paths from developmental risk to verbal working memory ($\beta = -.80$, $p < .01$) and nonverbal capacity ($\beta = .-.60$, $p < .01$) are statistically significant. These paths are in the expected direction given that lower risk index scores (indicating less potential experienced risk factors) are expected to be negatively related to the capacity variables (higher scores on capacity tasks). However, neither of the paths from socio-economic status to verbal working memory ($\beta = .15$, *ns*) and cognitive capacity ($\beta = .07$, *ns*) reach significance. The path estimates from the socio-economic status variable are in the expected direction, with the positive relationships indicating that higher scores on the socio-economic variable are related to higher scores on the capacity variables.

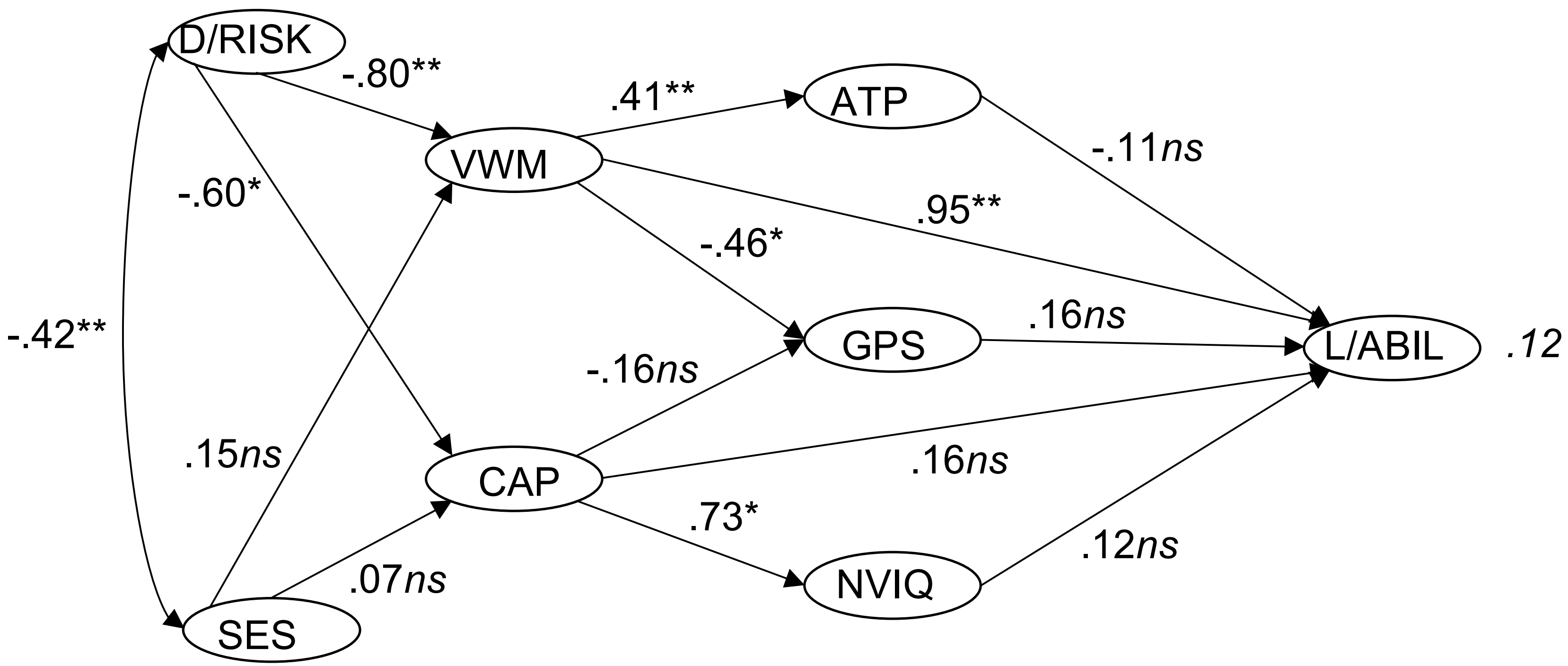

Figure 19. The cognitive capacity hypothesis structural model with parameter estimates. * $p < .05$, ** $p < .01$, *ns* = non-significant.

As shown in Figure 19, the paths from verbal working memory to global processing speed (β = -.46, p <. 01) and auditory temporal processing (β = .41, p <. 01) are significant. The estimated path from non-linguistic capacity to nonverbal IQ is significant (β = .73, p <. 01). However, the path from non-linguistic capacity to global processing speed is not significant (β = -.16, *ns*). Thus, the capacity variables do have specific significant effects on the other cognitive and perceptual variables.

The results of the cognitive capacity hypothesis model show that only one of the direct paths to language ability is significant, this is the path from verbal working memory (β = .95, p <. 001). Nonverbal IQ (β = .12, *ns*), auditory temporal processing (β = -.11, *ns*), nonverbal cognitive capacity (β = .08, *ns*) and global processing speed (β = .16, *ns*) do not have significant direct effects on language ability. Thus, the relationship between verbal working memory and language ability explains all of the variance in language ability in the cognitive capacity model. The non-linguistic capacity variable has no significant effect on language ability, but it does have a strong significant effect on nonverbal IQ. The results of this model appear to characterise a domain specific relationship in which verbal capacity is the sole predictor of language ability and nonverbal capacity is the sole predictor of nonverbal IQ.

This result supports Baddeley's (1986) domain-specific theory of working memory in which verbal working memory would be expected to be the sole predictor of language, rather than a combined predictive effect from cognitive capacity in general. However, the relationship between verbal working memory and language ability is also not surprising if verbal working memory tasks are just measuring language ability as MacDonald & Christiansen (2002) contend. For the domain specific relationship to be considered robust, it must be shown to be independent of reciprocal effects from language. In addition, the strength of the parameter estimate between verbal working memory and language ability suggests a possible collinear relationship between the two latent variables that would lend support to MacDonald and Christiansen's (2002) contention. The robustness of the domain specific relationship and the potential collinear relationship are investigated in the final structural model.

5.3.5 The Effects of Language Model

The final *a priori* model tests the effects of language on the cognitive and perceptual variables. The model with standardised parameter estimates is presented in Figure 20. It does not provide as good a fit to the data as the measurement model or the cognitive capacity model $\chi^2(397) = 452.43$, $p = .03$; RMSEA = .03.

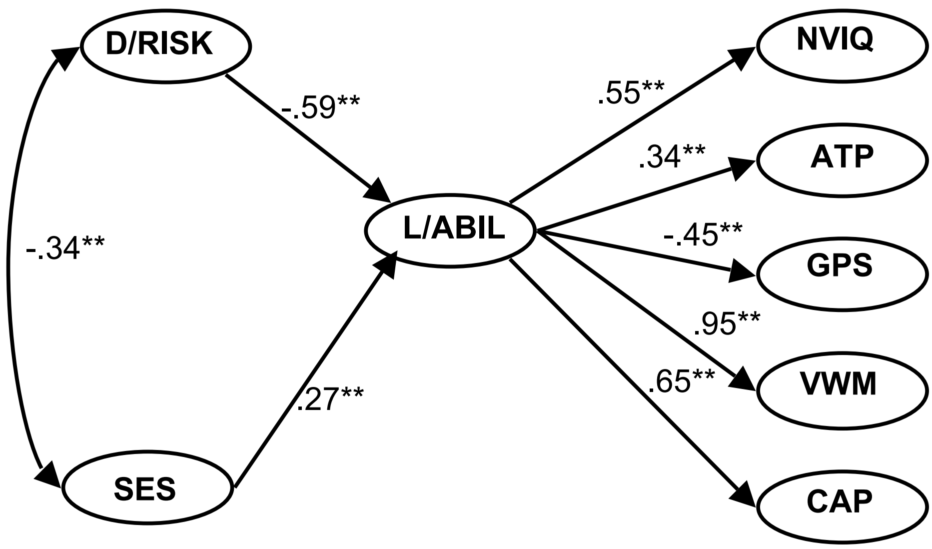

Figure 20. The effects of language structural equation model with parameter estimates. $^{**}p < .01$, $^{**}p < .01$.

However, all the estimated parameters in the effects of language model are statistically significant, and there are some interesting features to note. Firstly, the significant paths from language ability to all the cognitive and perceptual variables suggest that language ability is related to performance on these tasks to some degree. As can be seen from the path estimates in Figure 20, language ability explains nearly 40% of the variance in nonverbal cognitive capacity and approximately 30% of the variance in nonverbal IQ. It is unlikely that a similar shared type of processing or capacity causes this. Both nonverbal cognitive capacity and nonverbal IQ are measured by tasks that contain only visual and spatial processing requirements. In addition, it has been shown that cognitive capacity does not have a general predictive effect on language ability and nonverbal IQ. In the cognitive capacity hypothesis model there is a domain specific relationship between verbal working memory, nonverbal capacity and language ability and nonverbal IQ.

An alternative explanation for the results of the effects of language model is that language processing plays a significant role in the performance of these tasks. This is likely to be the result of language comprehension requirements during the training phase of the tasks, although this cannot be elucidated from the results of the present research. Wherever the effect may come from, it appears that it may be impossible to totally remove the effects of language from such nonverbal tasks, even when they are designed specifically to do so.

Secondly, the results of the effects of language model confirm the suspected collinearity between the latent variables language ability and verbal working memory, as do the correlations between the latent variables. Table 24 in Appendix D (p. 278) contains the correlation matrix for the latent variables. The path estimate from language ability to verbal working memory in the effects of language model is identical to the reverse path estimate in the cognitive capacity hypothesis model. Similarly, language ability explains 90% of the variance in verbal working memory in the effects of language model, which is almost identical to the results of the cognitive capacity model. Thus, it appears that verbal working memory, as measured by the nonword repetition task and digit span, is measuring almost exactly the same processing or abilities as the six subtests of the CELF-3.

The collinearity of verbal working memory and language ability in these models provides strong support for MacDonald and Christiansen's (2002) argument that verbal working memory tasks are merely special types of language processing tasks. In addition, it is difficult to explain the reciprocal effects evident in the two models within Baddeley's (1986) working memory theory. However, it is important to note that this collinear relationship is not simply two latent variables measuring the same type of processing, because both models include the effects of developmental risk and socio-economic status. Thus, there are combined biological and environmental effects that explain much of the variance in language ability as MacDonald and Christiansen (2002) suggest.

The collinear relationship between language ability and verbal working memory also suggests that the results of both the global processing speed and cognitive capacity models have been confounded by the inclusion of verbal working memory. The results of the global processing speed model do not suggest that removing verbal working memory would change it such that it would fit the variance in the data any better. However, the cognitive capacity model provided a good fit to the data and thus the model was reanalysed without the redundant verbal working memory latent variable. The resultant model is illustrated in Figure 21.

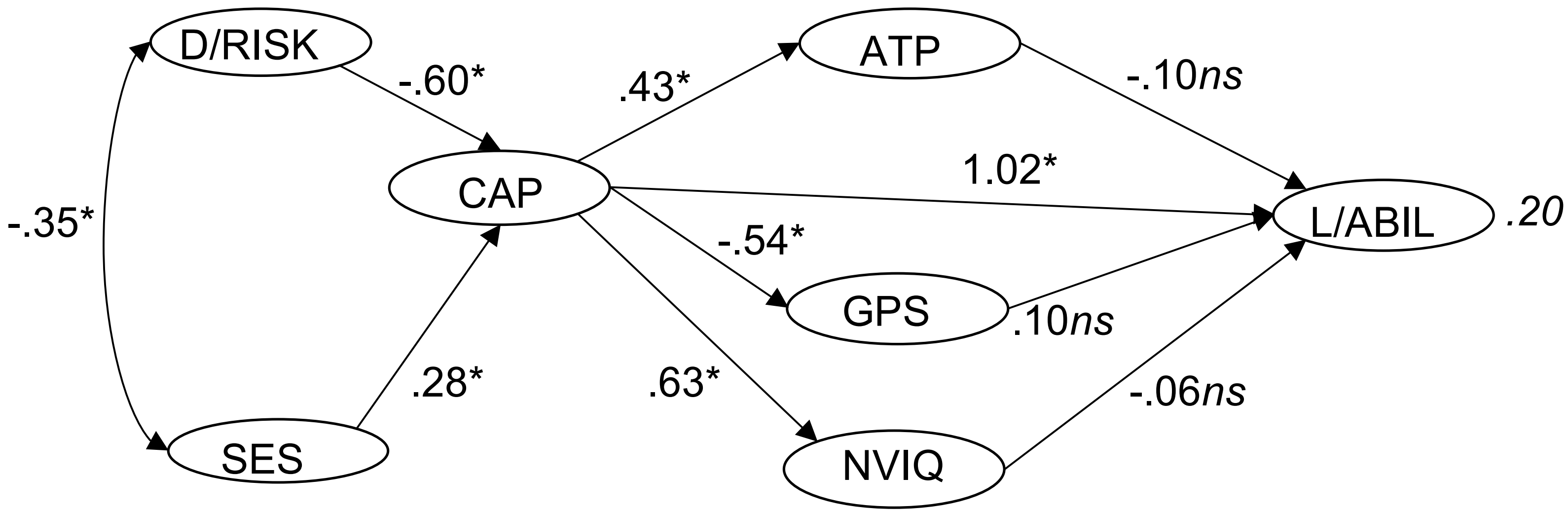

Figure 21. The modified cognitive capacity hypothesis model, with verbal working memory removed. * $p < .05$, ns =non-significant.

The second cognitive capacity model does not contain any of the verbal working memory observed or latent variables. Removing these variables had a detrimental effect on the fit of the model. It provides a poor fit to the data compared to the measurement model $\chi^2(340) = 400.24$, $p = .01$; RMSEA = .03. However, the model does appear to explain 80% of the variance in language ability. The cognitive capacity variable is the only significant predictor of language ability, although the path estimate is out-of-range. The model contains both direct and mediated paths from developmental risk and socio-economic status through cognitive capacity to language ability. The out-of-range estimate is likely to be a result of an overestimation due to the redundant non-significant mediated paths to language ability from nonverbal IQ, auditory temporal processing and global processing speed.

5.4 Discussion of Model Analyses and Study Hypotheses

Table 16 presents model fit indices for each model to aid comparison between hypotheses. As expected, the direct effects model provided a poor representation of the covariance matrix in the present sample. The model was constructed to represent the disconnected state of current research on SLI and thus, on language ability as a whole. The poor model fit provides support for the hypothesis that language ability may be better predicted by multivariate models that attempt to account for the inter-relationships between the cognitive, perceptual and developmental variables.

Table 16

Comparison of Fit Indices for Model Analyses

Model *Degrees of Freedom*	χ^2 *p*	χ^2/df	RMSEA	GFI	NNFI	CFI	Model CAIC
Measurement *df* = 377	416.89 *.08*	1.10	.03	.85	.98	.98	950.40
Direct Effects *df* = 398	669.92 *.0001*	1.70	.07	.78	.94	.95	1076.11
Processing Speed *df* = 393	543.42 *.0001*	1.38	.05	.81	.96	.95	979.93
Cognitive Capacity *df* = 390	434.18 *.06*	1.11	.03	.84	.98	.98	882.81
Effects of Language *df* = 397	452.43 *.03*	1.14	.03	.84	.98	.97	864.69
Cognitive Capacity – no VWM *df* = 340	433.11 *.01*	1.27	.03	.85	.97	.98	800.37

Note. Abbreviations are: Root Mean Square Error of Approximation (RMSEA), Goodness of Fit Index (GFI), Non-Normed Fit Index (NNFI), Model Consistent Akaike Information Criterion (CAIC) and verbal working memory (VWM).

The hypothesis that the developmental risk and socio-economic status variables would have a direct and mediated relationship with language through either global processing speed or cognitive capacity was not supported. When constructed with both direct and mediated paths, neither the global processing speed nor the cognitive capacity model would converge to a solution. Both models successfully converged once the direct paths from developmental risk and socio-economic status to language ability were removed.

The hypothesis that the global processing speed model would provide a reasonable fit to the data was not supported. It does not provide a good fit to the data from the present sample, although it represents the covariance matrix in a better manner than the direct effects model. There appear to be significant flaws in the specification of the global processing speed model, which if rectified, would transform it into a combination of the original cognitive capacity model and the effects of language model.

The hypothesis that the cognitive capacity model would provide the best fit to the data was supported superficially. The results of the analysis of this model indicate domain-specific relationships between types of cognitive capacity and language ability and nonverbal IQ. In the model, verbal working memory capacity alone predicts language ability, whilst the nonverbal capacity variable strongly predicts nonverbal IQ. However, the apparent domain specific pattern includes a collinear relationship between verbal working memory and language ability as illustrated in the analysis of the effects of language model. Thus, the results of the analysis of the cognitive capacity model are confounded by the inclusion of verbal working memory. Removing verbal working memory from the cognitive capacity model had a detrimental effect on the model χ^2 parameter through the reduction of the degrees of freedom, but did not alter the other fit indices markedly. In the modified cognitive capacity model, capacity mediates the effects of developmental risk and socio-economic status on all other variables, including language ability. It is likely that a number of these mediated paths are redundant and that the direct path from cognitive capacity is the only significant predictor of language ability.

The effects of language model reverses the relationships between language ability and all other cognitive and perceptual variables. As hypothesised, this model does not provide a good fit to the data in the present research; however, all parameter estimates are statistically significant, with language ability almost perfectly predicting verbal working memory. The results of this model support the contention that many tasks contain language processing requirements even when designed to be 'language-free'. One example of this is that participants may use verbal strategies and inner speech when they undertake these tasks. Such strategies and inner speech are likely to be idiosyncratic and individually specific. Thus, trying to remove the effects of language from experimental and other types of tasks is undoubtedly very difficult and may prove to be impossible. Performance on many of these tasks may be dependent on a child's understanding of the task requirements and on the basic conceptual assumptions therein, as well as the types of internal strategies undertaken.

In addition, the collinear relationship between the two latent variables, verbal working memory and language ability indicates they are measuring similar cognitive functioning or abilities as MacDonald and Christiansen (2002) suggest. The present research uses the subtests of the CELF-3, and digit span and the Nonword Repetition Task to predict language ability and verbal working memory respectively. When taken together, both sets of tasks appear to explain a considerable proportion of variance in each other providing strong evidence for MacDonald and Christiansen's (2002) argument regarding the similarity of language and verbal working memory tasks.

To summarise the results of the structural model analyses, it appears that the most salient feature is the effects of developmental risk and socio-economic status on other variables. That is, a number of inter-related factors including genetic influences, the home environment, parental education and occupation, exposure to reading and print materials, medical risk factors and motor and language development combine to directly and indirectly affect the types of cognitive and perceptual functioning included in the present research. It is suggested from the combination of the model results and the fact that the models would not converge with both direct and mediated effects from the exogenous variables, that developmental risk and socio-economic status probably have a direct significant effect on all cognitive and perceptual variables, including language. Furthermore, it is likely that the relationships between language and the cognitive and perceptual variables occur largely through the similarity of the effects from the exogenous variables. This contention is consistent with the notion that biological and experiential factors combine in complex ways to influence cognitive functioning generally, and language functioning in particular.

Chapter 6

General Discussion, Conclusions, Limitations and Implications

Chapter 1 reviewed the major areas of theoretical focus and methodological approaches in the large body of research on children with SLI for their relevance to language ability as a whole. Arising from this review, the major aims of the present study were to extend child language research by investigating the factors identified in research on SLI and their importance for normal language, and to address a number of theoretical and methodological limitations associated with previous research that have particular relevance for normal language development, as well as for SLI.

In addition, two contentions arising from the literature on children with SLI were addressed. The first was that children with SLI do not display a distinct disorder, but rather occupy the lower end of the language ability continuum and are not as immune to nonverbal intelligence difficulties as currently thought (Leonard, 1998). The second was that tasks measuring verbal working memory, both as a specific domain and as a separate type of processing, are really just language processing tasks by another name (MacDonald & Christiansen, 2002).

In order to address the limitations of previous research on SLI in relation to language as a whole, as well as Leonard's (1998) and MacDonald and Christiansen's (2002) contentions, a number of research questions and accompanying hypotheses were posed. The results of the present study will be discussed in this chapter with regard to the research questions, the issues identified in the review of previous research, and the limitations of the present study. Finally, the conclusions and implications of the results will be discussed in relation to their importance for child language research, SLI as a diagnosis, and potentially fruitful areas of further investigation.

6.1 Normal Distribution of Language Results and Number of Children Meeting the Language and Other Criteria for SLI

No specific hypotheses were forwarded regarding the question about the distribution of language ability scores in the non-clinical sample of children in the present study. The results indicated that the language scores of the 158 children participating in the present research were relatively normally distributed with 14% of the sample meeting the language criterion of a score more than 1.25 *SD*s below the mean on a standardised language test for a diagnosis of SLI. Six percent of children scored greater than 1.25 *SD*s above the mean on the CELF-3 and 80% of children scored within 1.25 *SD*s from the mean of 100 on the CELF-3. There were a larger number of children whose language scores were 1.25 *SD*s or more below the mean, than there were children with language scores greater than 1.25 *SD*s above the mean making the distribution of language scores slightly positively skewed.

It is possible that this positive skew occurred from two potential types of sampling bias. Firstly, it is possible that sampling bias occurred because more parents who thought their child may have a language or learning problem consented to participation. In addition, sampling bias could have occurred from teachers or principals selectively choosing the classes they wanted tested. Either or both of these types of bias would result in a sample containing a greater number of children with potential language problems than children with above average language. Unfortunately, the likelihood of some form of sampling bias makes estimating the incidence of children meeting the language criterion for SLI in the region tested impossible.

Of the 22 children meeting the language criterion, none had been formally diagnosed with SLI, although seven had been diagnosed as having an unspecified speech, language or learning problem. Sixty-eight percent of these children had not been identified with anything more severe than having some difficulties with schoolwork. This is consistent with the results of the Tomblin et al. (1997) epidemiological study, in which only 29% of the children who were identified as meeting the criteria for a diagnosis with SLI had previously been formally diagnosed. It is difficult to determine why the children in this study, most of whom had receptive language scores near 50 as well as low comprehension scores, had escaped attention. The majority of parents were not surprised to hear that their child had scored in the range indicating moderate to severe language problems, and neither were the children's teachers, yet few referrals to professionals had been made.

Amongst the group of children who met the language criterion for SLI, two did not meet the nonverbal IQ criterion with scores falling below 85 (79 and 82) on the Standard Progressive Matrices. All twenty-two children met the physical criterion, not having suffered any recent episodes of otitis media, hearing loss, oral function problems or gross physical or neurological insult. Therefore, 20 children from the 22 meeting the language criterion also appeared to meet the other criteria for a diagnosis of SLI.

6.2 Relationships between Cognitive, Perceptual and Developmental Variables and Language Ability

With regard to the second and third research questions about relationships between cognitive, perceptual and developmental variables across the normal range of language ability, a number of different hypotheses were posed. One specific hypothesis concerned the relationship of nonverbal IQ to language ability. A second set of hypotheses predicted linear relationships between cognitive and perceptual variables and language ability. Each of these general hypotheses is discussed separately in the following sections.

6.2.1 The Relationship between Nonverbal IQ and Language Ability

It was hypothesised that the nonverbal IQ scores of children meeting the language criterion for a diagnosis of SLI would be lower than children with average or above average language ability. The results of the different analyses suggest a complex relationship between language ability and nonverbal IQ that make a straightforward conclusion to this hypothesis difficult. The results of the correlational analyses indicate a strong relationship between language ability and nonverbal IQ. Nonverbal IQ shared the greatest variance with language ability in both the whole and matched sub-samples. Based on these results it was expected that there would be significant differences between language ability groups for nonverbal IQ indicating a linear relationship between nonverbal IQ and language ability. However, this did not occur.

The results of the quasi-experimental analyses in Chapter 4 indicated no significant differences between the nonverbal IQ scores of children in the low language ability group compared to the average language ability group. This is consistent with much of the previous quasi-experimental research on children with SLI, which has shown no significant difference between the nonverbal IQ scores of impaired and normal children. However, in the present research, there was a significant difference between the nonverbal IQ scores of children in the low and average language ability groups and the scores of the children in the high language ability group. That is, children in the high language ability group scored significantly higher on the Standard Progressive Matrices, on average, than children in the other groups.

An examination of the nonverbal IQ scores of the 22 children who scored lower than 1.25*SD* below the mean on the CELF-3 shows that the highest standard score is 101 and the lowest is 79. The average score is 91.1, which is almost one standard deviation below the mean on the Standard Progressive Matrices. Six children's scores are within the middle category of the average range (97 – 102), eight are in the lowest category of the average range (89 – 96), seven are in the highest category of the below average range (82 – 88), and one is in the lowest category of the below average range (74-81).

The nonverbal IQ scores of the children who scored lower than 1.25*SD* below the mean on the CELF-3 cannot be characterised as normal, as most fall into the low or below average ranges on the Standard Progressive Matrices. However, only 10 children from the 22 described here were included in the low language ability group due to the matching process. The mean nonverbal IQ score for the 10 children in the low language ability group was 92.2, which is slightly higher than that of the larger group of 22 children with poor language scores. In contrast, the mean nonverbal IQ score for the ten children in the average language ability group is 98.4, which is almost three standard scores lower than the mean nonverbal IQ score of 101 of the large group of 126 children with average language scores. It may be possible that the matching process used to create the groups unintentionally restricted the choice of children and thus the range of nonverbal IQ scores included in both the low and average language ability groups. Thus, with a restricted range due to the small group sizes, any real differences between the low and average language ability groups were not apparent.

It is also possible that the small numbers of children in each group may also have had a detrimental effect on the power to find a significant difference between the low and average language ability groups. Although the amount of variance explained in the omnibus ANOVA for nonverbal IQ (partial η^2 = .64) suggests adequate power to identify group differences, this may be the result of the large differences between the average score of the high language ability group and the scores of the other groups. There is almost a 1.5*SD* difference between the high and average language ability groups' scores, and more than 2*SD*s difference between the high and low language ability groups' scores.

Another possible explanation for these results, given the significant difference between the low and high language ability groups for nonverbal IQ, and the results of analysis of covariance and the structural models, is that nonverbal IQ does not have a simple linear relationship with language ability. In support of this contention, the significant difference between the low and high, and average and high language ability groups' mean nonverbal IQ scores suggests that nonverbal IQ does not have a consistent effect on language ability across the normal range. Secondly, the results of the ANCOVA analyses showed that removing the variance attributable to nonverbal IQ also removed any differences apparent between language ability groups for spatial span, the N-Term task and the Latin Square task.

This suggests shared variance for these tasks, nonverbal IQ and language ability. Finally, in the best fitting structural model, the cognitive capacity model, nonverbal IQ is not a significant predictor of language ability. The structural models take into account the associations between many variables, and it is clear from the model analyses that the associations vary to some extent with the inclusion of different variables. Given these findings it is likely that the relationship between language ability and nonverbal IQ is complex. The results of fitting the models of language ability to the data in the present study suggest that, like language ability, nonverbal IQ is predicted by cognitive capacity, which mediates the effects of social, environmental and developmental factors. However, in the effects of language model, language is a significant predictor of nonverbal IQ. Thus, the relationship between language ability and nonverbal IQ may be reciprocal to a certain extent and occur through similar influences from a general cognitive capacity factor which mediates the effects of social, environmental, and developmental factors.

The complexity of this conclusion regarding the relationship between nonverbal IQ and language ability has implications for interpreting the results of quasi-experimental studies in which no differences between children with SLI and normally developing children were found for nonverbal IQ scores. The assumption, when using this type of methodology, that no significant difference between groups equates to no relationship between nonverbal IQ and language ability, is simplistic. In these instances, any significant differences found on experimental tasks between children with SLI and children with normal language ability could be the result of a methodological artefact in which the criteria for SLI have given researchers an unwarranted assurance that their results will not be affected by nonverbal intellectual functioning. For example, Hoffman (2001) found that children with language impairments had poorer memory spans, especially for spatial information, than normally developing children. This significant finding was replicated in the present research. However, it was rendered non-significant when the variance accounted for by nonverbal IQ was removed from analyses. Hoffman argued that the results of her study indicated that children with language impairments had central executive functioning problems such that they could not exploit opportunities to disperse processing in dual task paradigms. It would be interesting to see if these results are still significant if nonverbal IQ were included as a covariate in analyses.

To summarise, the results of the present research indicate firstly, that using univariate and bivariate research methodologies and modes of analysis do not adequately account for the complex relationship between nonverbal IQ and language ability. Thus, it would be erroneous to assume that no relationship exists between these variables when using these methods. Secondly, the results indicate some support for the hypothesis that children in the low language ability group have lower nonverbal IQ scores than the children in the average and high language ability groups, although no significant differences were found between the low and average language ability groups.

Finally, the results of the present research also provide some support for the contention that children with SLI may represent the lower end of language and nonverbal IQ abilities, rather than a distinct disorder (Leonard, 1998). This conclusion also provides an explanation for the poor performance of children with SLI on many tasks that apparently have little or no linguistic processing requirements, such as memory scanning (Sininger, Klatztky & Kirchner, 1989), mental rotation (Johnston & Ellis Weismer, 1983), choice reaction time (Kail, 1994) and mental imagery (Savich, 1984).

6.2.2 The Relationships Between Language Ability and Cognitive, Perceptual and Developmental Variables

The discussion in the previous section highlights the potentially complex nature of the relationships and interrelationships between cognitive, perceptual and developmental variables. In light of this, the hypothesis positing linear relationships between language ability and the cognitive and perceptual variables is only superficially supported. The results of correlational analyses in Chapter 3 indicate that many tasks used in the present study have significant linear relationships with language ability. However, analyses in Chapters 4 and 5 demonstrate that the relationships between cognitive variables in particular are complex and are not readily represented by simple bivariate correlations as suggested by this hypothesis. The more complex relationships evident from the results of this study will be discussed in the following sections.

6.3 Tasks with Linguistic Processing Requirements and their Relationships with Language Ability

The fourth research question concerned the relationships between tasks with linguistic processing requirements and language ability. The study results do not support the hypothesis that tasks with linguistic processing requirements would be most strongly related to language ability. This hypothesis was based on MacDonald and Christiansen's (2002) argument that verbal working memory tasks are just special types of language tasks. As an extrapolation from this, it was contended that tasks with linguistic processing requirements, not just verbal working memory tasks, should show stronger relationships with language ability than tasks without linguistic processing requirements. Overall, the strongest correlations in both the whole and matched sub-samples were those between language ability, nonverbal IQ, the language risk index and nonword repetition. None of these variables are considered to be linguistic tasks, although there is evidence to suggest that the nonword repetition task is not entirely free from the effects of linguistic processing (Dollaghan, Biber & Campbell, 1993, 1995; Frisch, Large & Pisoni, 2000). In addition, other tasks with little or no linguistic processing requirements were strongly related to language ability.

Furthermore, the results of group difference analyses presented in Chapter 4 do not provide support for the hypothesis that tasks with linguistic processing requirements would have the strongest relationships with language ability. If this were the case, it would be expected that children whose language scores meet the criterion for SLI should perform at a lower level, particularly on linguistic processing tasks, than all other children. This was indeed the case. However, these children also performed poorly compared to other children on tasks that did not involve any overt linguistic processing requirements. This confirms the findings of many studies that have included tasks with and without language processing requirements (see Bishop, 1992 and Leonard, 1998 for reviews) in which children with SLI have performed at a lower level than normally developing children. The results are also consistent with those from the Dyck et al. (in press) methodological study of the criteria for pervasive developmental disorders. These authors found that children who performed badly on any measure were more likely to perform badly on other measures. That is, the children at the lower end of any distribution for any variable were also on the lower ends of the distributions of other variables. Thus, children with SLI may simply represent the tail of the sample for a whole range of skills.

In summary, neither the correlational results presented in Chapter 3 nor the group difference analyses presented in Chapter 4 give an accurate indication of the complexity of relationships within and between tasks with linguistic processing requirements and tasks without. The structural models analysed in Chapter 5 come closest to identifying the interrelationships underlying cognitive and perceptual abilities and social and developmental factors as they pertain to language ability.

6.4 Direct and Mediated Effects from Social, Environmental and Developmental Factors

The fifth research question concerned the effects of social, environmental and developmental variables on language ability. It was hypothesised that these variables would have both direct and mediated effects on language ability. The results of the analysis of the structural equation models do not support the hypothesis.

The hypothesis that there would be both direct and mediated effects on language ability from the social, environmental and developmental variables was tested in two structural equation models of language ability. The first tested the global processing speed hypothesis of language ability and the second tested the cognitive capacity hypothesis of language ability. The original models contained both direct and mediated paths, either through global processing speed for the first model, or cognitive capacity and verbal working memory in the second model. Neither of the models containing both direct and mediated paths would converge to a solution. This problem arose from including both paths, causing a linear redundancy that prevented the models from converging. The direct paths were removed as they were not the strongest of the two effects, and the models converged successfully when they included only the mediated paths. This suggests that the endogenous social, environmental and developmental variables do affect language ability, but indirectly through the mediation of other cognitive factors.

6.5 Structural Models of Language Ability

The sixth research question queried which structural model would provide the most efficient and parsimonious explanation for language ability. The question was associated with specific hypotheses about models. Firstly, it was hypothesised that a model of the separate direct effects of the study variables would provide a poor fit to the data. This was because the model merely represented the current unconnected state of language research and did not account for any interrelationships between the study variables. This hypothesis was supported. The direct effects model poorly represented the underlying structure of the data.

Secondly, it was hypothesised that both the global processing speed hypothesis and the cognitive capacity hypothesis models would provide reasonable representations of the data given the large body of research supporting these theories. This hypothesis was partially supported. The global processing speed hypothesis model provided a very poor fit to the data and appeared to be fatally mis-specified. In contrast, the initial analysis of the cognitive capacity hypothesis model provided the best fit to the data. However, when the results of the cognitive capacity model were examined in conjunction with those from the effects of language model, a collinear relationship between verbal working memory and language ability was apparent. Therefore, the results of the cognitive capacity hypothesis model are confounded by the inclusion of the redundant verbal working memory variable. The removal of this latent variable had a detrimental effect on the fit of the model as indicated by χ^2, but the other fit indices were relatively unaffected.

The modified cognitive capacity model indicates that nonverbal cognitive capacity mediates the effects of the social and developmental variables on all other variables, and it is the only variable with a significant direct effect on language ability. In addition, even though the model has a less than optimal fit and redundant paths, it explains a large percentage of the variance in language ability.

Although none of the models analysed provided a good fit to the data in the present research, the most surprising result is that the effects of language model fits the best, although, still not optimally. These results suggest that a model combining both the cognitive capacity hypothesis, and reciprocal effects from language, would most likely provide the best fit to the data from the present sample.

6.6 Structural Models and Verbal Working Memory

The final two research questions were concerned with the predictions of Baddeley's (1986) working memory model and MacDonald and Christiansen's (2002) contention that verbal working memory tasks are merely special types of language processing tasks. No specific hypotheses were offered. However, two models were constructed to test both predictions.

The cognitive capacity hypothesis model was constructed with separate latent variables representing verbal and nonverbal working memory or capacity as predicted by Baddeley's model. The results of the cognitive capacity model showed a domain-specificity in which verbal working memory was the only variable to significantly predict language ability and that nonverbal cognitive capacity significantly predicted nonverbal IQ. Thus, the cognitive capacity model provides support for Baddeley's theory, but does not discount MacDonald and Christiansen's argument.

The second model was constructed to test the reverse relationship from language ability *to* verbal working memory. If this path were significant it would indicate, as MacDonald and Christiansen (2002) suggest, that verbal working memory tasks and language ability tasks are measuring the same type of processing. The results of the analysis of this model indicate that language ability explains exactly the same amount of variance in verbal working memory as verbal working memory explains in the cognitive capacity model. Thus, the results of both models indicate an almost perfectly collinear relationship between verbal working memory and language ability providing strong support for MacDonald and Christiansen's claim regarding verbal working memory tasks and their relationship to language processing.

The large amount of shared variance (90%) between language ability and verbal working memory variables suggests that the task demands of the subtests of the CELF-3, and the digit span and the Nonword Repetition tasks are almost identical. This finding is not congruent with a large body of research predicated on the understanding that verbal working memory is a distinct domain from other types of working memory, and from language (Baddeley, 1986; Cowan, 1998; Ellis Weismer, 1998; Ellis Weismer, Evans & Hesketh, 1999; Gathercole & Baddeley, 1990; Gathercole, Hitch, Service & Martin, 1997; Gaulin & Campbell, 1994; Gillam, Cowan & Marler, 1998; Kail & Hall, 2001; Montgomery, 2002). However, the results of the present study are consistent with Van der Lely and Howard's (1993) conclusion that poor verbal working memory in children with SLI is more likely to be a result of poor language ability than a cause. In addition, the use of nonword repetition as a measure of verbal working memory has been qualified by research showing that performance on repetition of nonwords can also be dependent on the characteristics of the nonwords (Dollaghan, Biber & Campbell, 1993, 1995; Frisch, Large & Pisoni, 2000). These cautions about the nonword repetition task appear to be confirmed by the strength of the relationship between verbal working memory capacity and language ability.

Thus, the collinear relationship between the latent variables language ability and verbal working memory found in the present study provides strong support for MacDonald and Christiansen's (2002) contention that verbal working memory tasks are just different tasks that measure linguistic processing ability. Furthermore, this finding also provides support for the argument that separating verbal working memory processing from language ability is impossible as no separate functional entities like 'verbal working memory' exist (MacDonald & Christiansen, 2002).

A possible explanation for the collinear relationship between language ability and verbal working memory is that it is merely due to specific effects from the tasks used to measure the variables. That is, the characteristics of the tasks used may have caused an unusual relationship to occur. This may have been possible if the tasks were unusual or not well researched. However, it is unlikely that this has occurred, as the CELF-3, digit span and nonword repetition task, are used extensively to measure language and verbal working memory respectively in language research. Further evidence for the robustness of the relationship comes from the similarly predictive paths for both language ability and verbal working memory from the exogenous variables, developmental risk and socio-economic status in each model.

Both verbal working memory and language ability are directly predicted by the exogenous variables developmental risk and socio-economic status in the models. If verbal working memory and language tasks are measuring or accessing the same abilities, it seems that biological and environmental factors have a combined effect on language ability. This finding is consistent with Stromswold's (1998) suggestion that genetic and environmental factors operate in synergy upon language ability. From this view, children who are genetically at risk for language impairment may be sensitive to impoverished environments. In support of this, Bishop (2001) found different rates of heritability for nonword repetition between twins with SLI and normally developing twins. Nonword repetition ability was found to be highly heritable in the children with language impairments and poor nonword repetition performance was related to literacy problems. However, in normally developing children, nonword repetition ability was not heritable to the same degree. Bishop concluded that genetic factors were influential when literacy and language problems were severe and that environmental influences played a role when language problems were less severe. This is also consistent with the proposal that language ability is the product of biological factors and experience with language (MacDonald & Christiansen, 2002).

In summary, the results of the analyses of the cognitive capacity and effects of language models together suggest that cognitive capacity plays a role in the cognitive functioning of seven to nine year old children, although not in any domain specific capacity as suggested by Baddeley's (1986) model. In addition, the results of the present study are consistent with MacDonald and Christiansen's (2002) argument that it is impossible to divorce language processing from different functional aspects of language, or from separate functional entities purported to underlie language abilities.

6.7 General Discussion

The aims of the present research address a number of issues arising from the review of literature on SLI in Chapter 1. These were in relation to the investigation of child language ability as a whole. The first aim of the research was to investigate child language ability across the range of language in a non-clinical sample of children. This was to address the methodological issue arising from the application of statistical criteria for SLI in the selection of groups for quasi-experimental research. Three different methodologies were employed to investigate the question of whether the factors identified in research on SLI have importance for language as a whole.

Unfortunately, the study results do not indicate, as Leonard (1998) suggests, that the main theoretical areas of study on children with SLI have relevance and salience for research on the language of normally developing children. In the present research, many of the cognitive, perceptual, developmental, social and environmental factors measured were only significantly related to language ability when viewed in isolation. When interrelationships were taken into account, it was evident that many variables, including language ability, were only significantly related because of similar biological and environmental constraints on cognitive and perceptual functioning. A salient example of this is auditory temporal processing. The correlational results from the present research indicate only a modest significant relationship with language ability. The group difference analyses showed that children in the high language ability group were better at discriminating tones occurring rapidly than the children in the low and average language ability groups. This effect was nullified if the variance from language developmental risk factors was removed. In the structural models, auditory temporal processing had virtually no effect on language ability. However, depending on the structural model, the mediated paths from the developmental and social variables significantly predicted auditory temporal processing ability. In addition, as shown by the results of the effects of language model, language ability has a greater effect on auditory temporal processing ability than auditory temporal processing ability had on language, in any analyses. Thus, in the present study, this prominent area of research on children with SLI has little or no significance for normal language development, other than that it is affected by the same biological and environmental variables as language ability.

There are at least two reasons why this result could have occurred. Firstly, the version of the auditory repetition task used in the present research may have differed in some way to the tasks used in previous research, as the results were different to those expected. However, this is difficult to assess. Secondly, it may be possible that children with SLI who have temporal processing problems represent a separate population. This seems unlikely as 20 children in the present study met all criteria for a diagnosis of SLI.

The second aim of the present research was to examine the relationships between cognitive, perceptual, social, developmental and environmental factors with language ability. Three different methodologies were used to address this aim. These were correlational analyses, differences between language ability groups and structural models of the factors affecting language ability. Both the correlational and quasi-experimental methodologies suggested linear relationships between language ability and the cognitive, perceptual and social/developmental factors. However, these analyses also indicated complex interrelationships between factors. For example, language ability and nonverbal IQ are significantly related to a number of other factors, and each other. This was also demonstrated in the results of the analysis of covariance for the differences between language ability groups. From these results, any conception of the relationships between factors seemed unlikely to be simple and direct.

The third methodology addressed the complexity of interrelationships between factors, which were tested in *a priori* structural equation models. The results of the best fitting model indicated that cognitive capacity mediates the effects of social, environmental and developmental factors, and in that model was the only significant predictor of language ability. However, these relationships were further qualified by the results of the effects of language model, which indicated that language ability has a significant effect on all of the cognitive and perceptual variables in the present research. Thus, the relationships between cognitive and perceptual abilities and nonverbal IQ and language ability are complex and most likely reciprocal.

The finding that no single factor is a significant predictor of language ability and that the interrelationships between variables are complex and reciprocal poses a problem for many of the theories currently used as potential explanations for SLI, and thus for explanations of language as a whole. It appears that poly-theoretical and multivariate approaches may have greater utility in the development and testing of inclusive models of language ability than unitary explanatory theories and quasi-experimental methodology. Thus, by using an integrative theoretical approach it is possible to investigate the relative importance of factors and the way they interact.

The third aim of the present research was to include nonverbal IQ as a study variable. This was to investigate the argument that previous research has not provided a clear understanding of the relationship between language ability and nonverbal intelligence. This is due to the nonverbal IQ criterion for a diagnosis of SLI ensuring that children in research groups have comparable nonverbal intelligence. Thus, there are generally no differences found between groups of children with SLI and normally developing children on nonverbal IQ scores. Because of this, nonverbal IQ is rarely included as a study variable in research comparing children with SLI to normally developing children. However, the results of the present research indicate that nonverbal IQ is significantly and complexly related to language ability. This relationship is evident in bivariate correlations and in analysis of variance, where results were rendered insignificant when the variance accounted for by nonverbal IQ was removed. Interestingly, there was no significant difference in mean nonverbal IQ between groups of children with low language ability and children with normal language ability. This is similar to the type of results evident in previous quasi-experimental research. However, in the present study, there was a significant difference in nonverbal IQ between the children with low and average language ability and the children with high language ability. This may have occurred unintentionally through the group matching procedure, which restricted the choice of children and thus perhaps the range of IQ scores sampled. The matching procedure may have also adversely affected the power of this analysis to detect more subtle differences given the large differences between the high language ability group's mean scores and the mean scores of the other groups. Another possible explanation is that nonverbal IQ and language are related in a more complex non-linear manner.

In support of the position that nonverbal IQ is complexly related to language ability, the results of structural equation models analysed in Chapter 5 indicate a relationship that contradicts a simple linear characterisation. It appears that nonverbal IQ is predicted predominantly by non-linguistic cognitive capacity which mediates the effects from exogenous social and developmental variables. There is no direct significant relationship from nonverbal IQ to language ability. To confuse the issue further, in the present study, language has a significant effect on all cognitive and perceptual variables, including nonverbal IQ. This suggests there may be reciprocal effects from language to nonverbal IQ that were only tangentially examined in the present study. Despite this, it is likely that the application of the nonverbal IQ criterion for SLI in previous research has obscured the complex relationship between language ability and nonverbal intelligence.

The fourth aim of the present research was to investigate Baddeley's (1986) working memory model and MacDonald and Christiansen's (2002) argument that verbal working memory tasks are merely special types of language processing tasks. If MacDonald and Christiansen's argument is true, then research finding significant problems in verbal working memory for children with SLI, especially as measured by nonword repetition, may have been confounded by similarity of task demands.

This potential confound was addressed using a number of different analytical approaches in the present research. These included an examination of correlational data, analysis of differences between language ability groups, and analysis of structural equation models. The correlational and group difference results indicated that verbal working memory tasks, in particular nonword repetition, have significant linear relationships with language ability. In the case of nonword repetition, this relationship was nullified when the variance attributed to the language risk index was accounted for in analyses.

Two structural models were proposed to test Baddeley's (1986) theory and MacDonald and Christiansen's (2002) argument about verbal working memory. Baddeley's working memory model would predict domain specific relationships between verbal and nonverbal working memory measures and language ability and nonverbal IQ respectively. This prediction was tested in the cognitive capacity hypothesis model. Initial analyses showed that the model results provided strong support for a structural relationship such as that predicted by Baddeley's model. However, verbal working memory was the only variable to be a significant predictor of language ability. Indeed, it almost perfectly predicted language ability, raising suspicions of a collinear relationship. A second model tested the effects of language ability on the cognitive and perceptual variables. It indicated a relationship from language ability to verbal working memory that was the same strength and predictive value as the reverse relationship had in the previous model.

Therefore, the cognitive capacity and effects of language structural models provided strong evidence of a collinear relationship between verbal working memory and language ability providing support for MacDonald and Christiansen's (2002) argument. Thus, the evidence from the results of the present study suggests that tasks used to measure verbal working memory are significantly related to language ability, but that this is most likely due to a high similarity between task demands as the collinear relationship suggests. Additional support for this contention is provided via the existence of significant predictive paths from socio-economic status and developmental risk to both language ability and verbal working memory in the cognitive capacity and effects of language models respectively.

Indeed, the strength of the relationship between language and verbal working memory tasks most likely arises from the similarity of the effects of biological and environmental factors on cognitive functioning in general.

The MacDonald and Christiansen (2002) argument regarding verbal working memory and language ability tasks also suggests that other tasks with linguistic processing requirements would be more likely to be strongly related to language ability than tasks without these requirements. Unfortunately, the results of the present study do not totally support this line of reasoning. The bivariate correlations between language ability and tasks with linguistic processing requirements in general were not major contributors to the strength of the relationships, especially in comparison to nonverbal IQ and the language developmental risk index. The reasoning underlying this particular study hypothesis is probably simplistic in light of the complex multivariate relationships apparent in the model analyses. It appears that, in the present study, verbal working memory tasks and language ability tasks are measuring the same aspects of cognitive processing, and that the cognitive abilities underlying performance in those tasks are directly affected by social, developmental and environmental factors.

The final aim of the research was investigate the type of relationships that developmental, social and environmental factors have with language ability. These factors are often not considered in quasi-experimental research designs, but are recognised as a part of the epidemiological background for language as a whole. The present study includes different measures of these factors in an attempt to gain an understanding of the type of biological and environmental influences that are important for language ability. It is obvious from the study results from all three analytical approaches that these factors play an important role in determining a child's language and other abilities. There are strong bivariate linear relationships, differences between language ability groups, and predictive effects in structural models for these variables and language ability and verbal working memory. The results from all levels of analysis in the present research considered together suggest that the biological and environmental factors are the most salient for cognitive functioning in general and that their effect must be taken into account in research on language development.

To conclude, the present research has extended current methodological and theoretical knowledge with respect to the factors of importance to language ability. The major cognitive, perceptual and social/developmental theories were examined for their importance to child language ability. Many of the variables measured within these theories were linearly related to language ability. However, most study analyses indicated that language and the cognitive, perceptual and social/developmental variables were complexly interrelated. In addition, and somewhat unexpectedly, language ability appears to have a significant effect on all the cognitive and perceptual study variables. A possible means of explaining this is suggested by Goldberg and Costa's (1981) theory of descriptive systems. These authors assert that language is the fundamental natural descriptive system of human-kind, and thus has a profound effect on the cognitive organization of a large range of culturally-bound information. Thus, from this perspective, language ability would have a significant and inextricable effect on the cognitive and perceptual functioning measured in this study. Therefore, it could be argued that language ability is fundamental to human cognitive functioning, and as such is inextricably woven into the fabric of human existence. Removing it to study specific language-based disorders, measure nonverbal functioning, or to design tasks for experimental purposes, may be impossible.

6.8 Limitations of the Present Study

All research is associated with limitations that affect its generalisability. The present research is no exception and a number of prospective limitations are discussed in this section.

The first potential limitation of the present study is the bias evident in the language scores of the child participants. This occurred despite the steps taken to reduce this possibility (see Chapter 2, section 2.1). As discussed in Chapter 2, and in section 6.1 of this chapter, the sample included more children with language scores below 1.25*SD*s below the mean, than children with language scores 1.25*SD*s above the mean. There are a number of possible sources for this positive skew. These include the likelihood of non-sampling bias from more parents who perceived their child to have a problem with language, or at school, consenting to participation than parents who did not have this perception about their child. In addition, it was clear from the initial stages of the research that there was a predisposition of school staff to choose classes to participate that contained children that the principal or teacher were keen to have tested. Whilst this was a good strategy for benefiting individual students, it means that the results of the present study must be generalised to other populations with caution.

In addition to sampling bias causing difficulties for generalisation of results, it also limited the number of children that could be included in the language ability groups. There were only 10 children in the sample who had language scores 1.25*SD*s above the mean. This was the limiting factor in the creation of the language ability groups. Thus the groups only contained 10 children each, which may have restricted both the range of scores of the groups, and the power to find a difference between low and average and average and high language ability groups. Not surprisingly, the most consistent differences found between groups were between the low and high language ability groups for almost all study variables.

Another point to note regarding sampling is that considerably more mothers than fathers or guardians answered the questions on the parental interview. The socio-economic variables in the present study were the participating parent's occupation and years of parental education. In general women do not complete as many years of education as men and thus do not attain professional positions at the same rate (Australian Bureau of Statistics Census, 2001). As more mothers responded to the parental interview this is a potential problem. However, including only the mother's occupation and years of education has most likely only restricted the range of these variables. Only the higher end of the distribution has not been sampled in the present research if men achieve higher educational levels and more professional occupations than women. Thus, it is possible that the socio-economic variable has been quantitatively underestimated. If the father's socio-economic information were included in the research only a quantitative change would occur in the results. There would be no qualitative difference in the relationships reported.

Another sampling issue that has particular relevance for comparisons with other research and normative samples is that the sample used in the present research is age-restricted. Whilst a broader range of ages of participants would have been beneficial, the sample size requirements would have increased dramatically in order to include enough children in each age range. This was considered unrealistic given the demands of the data collection stage of the research. Thus, any comparisons between the results of the present research and other research must take the ages of the participants into account.

A further limitation of this study is related to sample size. Unfortunately, while the different types of analyses used in the present research provided diverse means to examine the data, they also had diverse sample size requirements. In an effort to estimate optimal and realistic sample sizes, particularly for structural equation modelling (SEM), a number of factors were taken into consideration. These included the number of variables to be entered into analyses and statistical research showing that in some cases samples of greater than 100, but less than 200, are adequate when using maximum likelihood estimation procedures in SEM (Bentler & Yuan, 1999). In the present research the sample size of 158 was considered adequate, and even perhaps on the large side for the correlational analyses; however, it could be considered small for structural equation modelling purposes (MacCallum & Austin, 2000). Therefore, the results of the structural equation models in particular may have been affected by restricted sample size.

Another potential limitation of the present research also involves the structural models. A stronger evaluation of the reciprocal, collinear relationship between verbal working memory and language ability would have been to include both paths in the one model. However, assessing non-recursive models on LISREL involves restrictions on predictive paths to the variables argued to have a reciprocal relationship (Jöreskog & Sörbom, 2003). This restriction is that variable A must not be predicted by the same variables as variable B. In the models tested in the present research, it was hypothesised that socio-economic status and developmental risk would have direct effects on verbal working memory in the cognitive capacity hypothesis model, and on language ability in the effects of language model. Thus, reciprocal paths between verbal working memory and language ability were not possible given this restriction.

The final limitation concerns causality. The results of this study are not intended to infer any type of causal relationship between the study variables and language ability. The focus of the study was on the relationships between variables and language ability and potentially predictive systemic models.

6.9 Implications of the Study Findings and Future Directions

The results of the present study indicate a number of implications for future research on language, verbal working memory and SLI. These will be discussed in this section along with some suggestions for profitable avenues of future research.

Firstly, it is apparent from the three levels of data analysis undertaken in this study that many of the factors identified through research on SLI do not have significant direct relationships with language ability as a whole. The pattern is far more complex than simple correlations or differences between groups would suggest. This indicates that multivariate research may be the only means of elucidating the combination of biological, environmental, and cognitive factors that affect children's language ability.

A number of opportunities for future multivariate research are suggested by the findings of the present research. The cognitive capacity hypothesis model could be modified to remove the redundant paths from the other cognitive and perceptual variables to language ability and tested on both larger samples and longitudinal data. In addition, it would be profitable to investigate the model on cross-cultural samples. Testing the model in various other circumstances would enable replication (or not) of the present study results and indicate the stability, importance and size of the effects of the social, developmental and capacity variables over time. In addition, the effects of language model in the present study indicated significant effects from language to all other cognitive and perceptual variables. This finding suggests that removing the effects of language from experimental tasks may be impossible. However, structural models would be good tools with which to estimate the effects of language on different cognitive and perceptual abilities. Once estimated, the effects of language on particular types of functioning could be controlled or accounted for in experimental designs.

Secondly, the results of the present research indicate that verbal working memory tasks may actually be measuring language ability. This finding poses a problem for the use of the nonword repetition task in particular, and perhaps verbal working memory theories in general. The reciprocal, collinear relationship found in the present research between verbal working memory and language ability needs to be examined further and replicated on other samples. For example, the analyses undertaken in the present study do not indicate whether all tasks purported to measure verbal working memory have the same relationship with language ability. Furthermore, many researchers and clinicians use the nonword repetition and digit span tasks as verbal working memory tasks, but in other theoretical conceptions they may be classified as short term memory tasks. In addition, the collinear relationship found in the present research may be specific to the combination of digit span and nonword repetition, or may be entirely due to the effects of nonword repetition.

A number of different methods could be applied to the examination of verbal working memory, in particular nonword repetition, and language. For example event related potential and imaging methods could provide information about the type, location and level of similarity of activation during verbal working memory and language tasks. This type of research would provide an alternative to experimental and modelling methods and thus provide converging evidence for or against the possibility that verbal working memory tasks are in effect language processing tasks. Imaging studies have already shown that the left lateral frontal and inferior parietal lobes are activated in verbal working memory tasks involving the phonological loop component of Baddeley's working memory model (see Gazzaniga, Ivry & Mangun, 2002 for a review). It may be that simple tasks involving holding verbal information in immediate memory are processed in the phonological loop, but more complex tasks such as nonword repetition are processed with lexical and language resources.

Further research may indicate a convergence of evidence to suggest that verbal working memory is not a separate construct from language processing, or that nonword repetition, in particular, is measuring language processing. If this were the case, then nonword repetition would lose its utility as a measure of verbal working memory. However, the task need not be eliminated from language research entirely as, through its strong relationship to language processing, it would have great utility as an early indicator of language impairment. Bishop (2001) found that nonword repetition performance is highly heritable in children with impaired language ability and Simkin and Conti-Ramsden (2001) used nonword repetition successfully as a marker for SLI. The nonword repetition task has benefits such as simplicity of administration and scoring, it can be used with very young children and children find it fun to do. Thus, the nonword repetition task is an ideal tool for early identification of language problems. In addition, the task has clinical utility in screening and intervention programs in general, as children with language impairments are also likely to suffer other types of impairments.

The final implication for language research, and research on SLI in particular, is that the results of the present study indicate that SLI may not be a distinct language-bounded disorder. A non-clinical school-based sample was sought in the present research. The focus was on the normal range of language ability of the children in the sample and it was not expected that more than one or two children would meet some of the criteria for a diagnosis of SLI. Therefore the finding that 14% of participants met all the criteria for a diagnosis of SLI was surprising, even after accounting for the probable sampling bias.

It is not clear why none of these children had been formally diagnosed with SLI. From discussions with parents during data collection it appears that two factors may affect the rates of diagnosis. The first is that many of the parents of the children with language impairments in the present study did not think that their child's speech or language difficulties were abnormal before he or she went to school. Most were not concerned until after the child had started school and teachers had suggested there was a problem. It is likely that multiple factors affect whether parents identify problems before their child goes to school. These include having a family history of impairments ("his father was the same, so I didn't think anything of it") lower education levels, and a poor socio-economic environment making accessing specialist care, or early intervention options less likely.

Regardless of the number of children who were identified as having language impairments in the present study, the fact remains that study analyses also indicate that SLI is not a distinct disorder. For example, converging evidence from all three methods of analysis suggests that children with SLI-like impairments in the present study represent the lower end of the language ability continuum rather than a separate population. These children also performed at the lower end of all other types of functioning measured. This is consistent with the results of the Dyck et al. (in press) study, in which almost all children who performed poorly on any measure also performed poorly on other measures. These authors argued that there seems to be nothing 'specific' about pervasive developmental disorders. That is, children with problems in one area, including language, were more likely to have multiple problems. Results from the structural models analysed in the present research indicate that the poor level of functioning of the children with low language scores is a product of biological factors and environmental conditions that negatively affect their cognitive capacity, which in turn affect their global cognitive functioning.

There are qualifications to the contention that SLI is not a distinct language-based disorder. Firstly, in the present research language has been shown to have an influence on performances on cognitive and perceptual tasks. Therefore, children with language impairments are doubly handicapped in experimental and clinical testing. That is, their performance on any type of experimental or clinical task will be impaired if they have lower than average comprehension, and their verbal performance will be impaired if they have expressive difficulties. Thus, it is difficult to assert with any surety whether children with SLI or other language impairments do have a specific language problem, or whether a more global impairment is present, as all test and task results must be confounded by the language requirement.

The second qualification is that although cognitive capacity appears to be the major mediating variable in the present research, the final structural model still did not give an optimal fit to the data. This model should be investigated further and converging evidence sought from alternative paradigms. A more general capacity theory would need to encompass neural mechanisms that may be potentially impaired. In this regard there is great scope for connectionist models to be used to investigate capacity limitations arising from different sources and how these affect language and other processing.

6.10 Significance of the Present Research

The present research extends previous research on child language by incorporating a number of prominent theories of language impairment and investigating the importance of these factors for language ability as a whole. The study takes a poly-theoretical and multi-methodological approach. Two data collection methods and three different types of data analysis were utilised. These included testing a relatively large non-clinical sample of children on language, cognitive and perceptual tasks, interviewing the children's parents and applying correlational, quasi-experimental and structural equation modelling analyses. Thus, the present research significantly extends language research methodologically and theoretically.

Results from the present study indicate a number of main findings that are of importance for language research, verbal working memory research and conceptions of SLI as a diagnosis. To summarise the findings, some of the factors that have been identified in research on SLI have importance for language ability as a whole, but only when the complex inter-relationships between variables are taken into account. Results indicate that social, environmental and developmental factors have direct and indirect effects on language ability. Cognitive capacity mediates the effects from the social, environmental and developmental factors on language and nonverbal intelligence.

Social, environmental and developmental factors appear to be of great importance in contributing to a child's cognitive abilities. Whilst this finding is not unexpected, it is important to note that these factors are sometimes not controlled for in research on language impairments. In addition, social, environmental and developmental factors are often considered to be beyond the professional realm of the psychologist and constitute 'background' factors that are recognised, but not addressed. It is argued that these factors should become part of the realm of all language professionals who work with children. Some possible means for achieving this are the development of psycho-educational programs for expecting parents, childcare providers and teachers, and the development of early screening programs for language, and corresponding impairments.

Other results from the structural equation models indicate that verbal working memory has an almost perfectly collinear relationship with language ability. This finding provides support for MacDonald and Christiansen's (2002) contention that verbal working memory tasks are actually measuring language processing and presents a problem for verbal working memory accounts of language impairments. In addition, a model of the effects of language on other cognitive and perceptual variables indicates that language ability has a pervasive effect on the performance of all other types of processing. Thus, it may be not be possible to divorce the effects of language from performance on cognitive and perceptual tasks, requiring the development of novel experimental and statistical methods to control for language ability in future research.

Finally, the results from the present research provide support for Leonard's (1998) contention that children with SLI may not suffer a distinct disorder. It is argued that SLI would be more profitably categorised as a pervasive syndrome of related impairments that arises from limitations in processing capacity and includes nonverbal functioning.

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders (4th ed.)*. Washington, D C: Author.

Australian Bureau of Statistics. (2001). *2001 census data.* Retrieved May 15, 2003 from http://www.abs.gov.au

Baddeley, A. (1986). *Working memory*. Oxford, England: Oxford University Press.

Bentler, P. M., & Yuan, K-H. (1999). Structural equation modeling with small samples: Test statistics. *Multivariate Behavioral Research, 32*(2), 181-187.

Bernstein, L. E., & Stark, R. E. (1985). Speech perception development in language-impaired children: A four-year follow-up. *Journal of Speech and Hearing Disorders, 50*(1), 21-30.

Bishop, D. V. M. (1992). The underlying nature of specific language impairment. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 33*(1), 3-66.

Bishop, D. V. M. (2001). Genetic influences on language impairment and literacy problems in children: Same or different? *Journal of Child Psychology and Psychiatry and Allied Disciplines, 42*(2), 189-198.

Bishop, D. V. M., Bishop, S. J., Bright, P., James, C., Delaney, T., & Tallal, P. (1999). Different origin of auditory and phonological processing problems in children with language impairment: Evidence from a twin study. *Journal of Speech, Language and Hearing Research, 42,* 155-168.

Bishop, D. V. M., Briscoe, J., & Norbury, C. F. (1999) *Language and literacy development: A comparison of children with specific language impairment, children with moderate hearing losses, and normally developing children* [Web Page]. URL http://epwww.psych.ox.ac.uk/oscci/Studay%20A%20Feedbacka.thm [Retrieved April 15, 2000].

Bishop, D. V. M., Carlyon, R. P., Deeks, J. M., & Bishop, S. J. (1999). Auditory temporal processing impairment: Neither necessary nor sufficient for causing language impairment in children. *Journal of Speech, Language, and Hearing Research, 42*(6), 1295-1310.

Bishop, D. V. M., North, T., & Donlan, C. (1996). Nonword repetition as a phenotypic marker for inherited language impairment: Evidence from a twin study. *Journal of Child Psychology and Psychiatry, 33*, 1-64.

Botting, N., & Conti-Ramsden, G. (2001). Non-word repetition and language development in children with specific language impairment. *International Journal of Communication Disorders, 36*(4), 421-432.

Brinton, B., & Fujiki, M. (1999). Social interactional behaviors of children with specific language impairment. *Topics in Language Disorders, 19*(2), 49-69.

Briscoe, J., Bishop, D.V.M., & Frazier Norbury, C. (2001). Phonological processing, language, and literacy: A comparison of children with mild-to-moderate Sensorineural Hearing Loss and those with Specific Language Impairment. *Journal of Child Psychology and Psychiatry, 42*(3), 329-340.

Burgess, S.R. (2002). The influence of speech perception, oral language ability, the home literacy environment, and pre-reading knowledge on the growth of phonological sensitivity: A one year longitudinal investigation. *Reading & Writing, 15*(7-8), 709-737.

Cacace, A. T., & McFarland, D. J. (1998). Central auditory processing disorder in school-aged children: A critical review. *Journal of Speech, Language, and Hearing Research, 41*(2), 355-373.

Campbell, T., Dollaghan, C., Needleman, H., & Janosky, J. (1997). Reducing bias in language assessment: Processing-dependent measures. *Journal of Speech, Language, and Hearing Research, 40*(3), 519-525.

Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the Raven Progressive Matrices Test. *Psychological Review, 97*, 404-431.

Cerella, J., & Hale, S. (1994). The rise and fall in information-processing rates over the lifespan. *Acta Psychologica, 86,* 109-197.

Cohen, J., Flatt, M., MacWhinney, B., & Provost, J. (1994). *Psyscope* (Version 1.0) [Computer software and manual]. Retrieved from http://psyscope.psy.cmu.edu/

Cowan, N. (1998). Short-term memory, working memory, and their importance in language processing. In R. B. Gillam (Ed*), Memory and language impairment in children and adults: New perspectives* (pp. 3-27). Gaithersburg, Maryland: Aspen Publishers.

Daneman, M., & Carpenter, P. A. (1983). Individual differences in integrating information between and within sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*(4), 561-584.

Deary, I. J., & Stough, C. (1996). Intelligence and inspection time: Achievements, prospects, and problems. *American Psychologist, 51,* 599-608.

de Baessa, Y., Fernandez, F.J. (2003). Home factors in academic achievement. *Revista de Psicologia, 21*(2), 312-331.

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in normal and aphasic speakers. *Psychological Review, 104,* 801-838.

Dempster, F. N. (1981). Memory span: Sources of individual and developmental differences. *Psychological Bulletin, 89*(1), 63-100.

Dollaghan, C., Biber, M., & Campbell, T. (1993). Constituent syllable effects in a nonsense-word repetition task. *Journal of Speech and Hearing Research, 36*(5), 1051-1054.

Dollaghan, C. A., Biber, M. E., & Campbell, T. F. (1995). Lexical influences on nonword repetition. *Applied Psycholinguistics, 16*, 211-222.

Dyck, M. J., Hay, D., Anderson, M., Smith, L. M., Piek, J., & Hallmayer, J. (in press). Is the discrepancy criterion for defining developmental disorders valid? *Journal of Child Psychology and Psychiatry 45*(0), 1-17.

Ellis Weismer, S. (1998). Capacity limitations in working memory: The impact on lexical and morphological learning by children with language impairment. In

R. B. Gillam (Ed), *Memory and language impairment in children and adults: New perspectives* (pp. 47-63). Gaithersburg, Maryland: Aspen Publishers.

Ellis Weismer, S., Evans, J., & Hesketh, L. J. (1999). An examination of verbal working memory capacity in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 42*(5), 1249-1260.

Evans, G.W. (2004). The environment of childhood poverty. *American Psychologist, 59*(2), 77-92.

Evans, G. W., & Maxwell, L. (1997). Chronic noise exposure and reading deficits: The mediating effects of language acquisition. *Environment and Behavior, 29*(5), 638-656.

Evans, G. W., Maxwell, L. E., & Hart, B. (1999). Parental language and verbal responsiveness to children in crowded homes. *Developmental Psychology, 35*(4), 1020-1023.

Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research, 18*(3), 382-388.

Foy, J.G., & Mann, V. (2003). Home literacy environment and phonological awareness in preschool children: Differential effects for rhyme and phoneme awareness. *Applied Psycholinguistics, 24*(1), 59-88.

Friel-Patti, S. (1999). Specific language impairment: Continuing clinical concerns. *Topics in Language Disorders, 20*(1), 1-13.

Frisch, S. A., Large, N. R., & Pisoni, D. B. (2000). Perception of wordlikeness: Effects of segment probability and length on the processing of nonwords. *Journal of Memory and Language, 42,* 481-496.

Fry, A. F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. *Psychological Science, 7*(4), 237-241.

Gallagher, T. M. (1999). Interrelationships among children's language, behavior, and emotional problems. *Topics in Language Disorders, 19*(2), 1-15.

Gathercole, S. E. (1995). Is nonword repetition a test of phonological memory or long- term knowledge: It all depends on the nonwords. *Memory & Cognition, 23*(1), 83-94.

Gathercole, S. E., & Adams, A-M. (1993). Phonological working memory in very young children. *Developmental Psychology, 29*(4), 770-778.

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*(3), 336-360.

Gathercole, S. E., Hitch, G. J., Service, E., & Martin, A. J. (1997). Phonological short-term memory and new word learning in children. *Developmental Psychology, 33*(6), 966-979.

Gathercole, S. E., & Pickering, S. J. (2000). Assessment of working memory in six and seven year old children. *Journal of Educational Psychology, 92*(2), 377-390.

Gathercole, S. E., Willis, C., Elmslie, H., & Baddeley, A. D. (1991). The influences of number of syllables and wordlikeness on children's repetition of nonwords. *Applied Psycholinguistics, 12*(3), 349-367.

Gaulin, C. A., & Campbell, T. F. (1994). Procedure for assessing verbal working memory in normal school-age children: Some preliminary data. *Perceptual and Motor Skills, 79,* 55-64.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2002). *Cognitive neursoscience: The biology of the mind (2nd ed)*. New York: W.W. Norton.

Gillam, R. B., Cowan, N., & Marler, J. A. (1998). Information processing by school-age children with specific language impairment: Evidence from a modality effect paradigm. *Journal of Speech, Language, and Hearing Research, 41*(4), 913-926.

Gillam, R. B., Hoffman, L. M., Marler, J. A., Wynn-Dancy, M. L. (2002). Sensitivity to increased task demands: Contributions from data-driven and conceptually driven information processing deficits. *Topics in Language Disorders, 22*(3), 30-48.

Goldberg, E., & Costa, L. D. (1981). Hemisphere differences in the acquisition and use of descriptive systems. *Brain and Language, 14,* 144-173.

Gopnick, M., & Crago, M. (1991). Familial aggregation of a developmental language disorder. *Cognition, 39*, 1-50.

Gregory, R. J. (1996). *Psychological testing: History, principles and application (2nd ed).* Boston, Allyn and Bacon.

Hale, S., Bronik, M. D., & Fry, A. F. (1997). Verbal and spatial working memory in school-age children: Developmental differences in susceptibility to interference. *Developmental Psychology, 33*(2), 364-371.

Hale, S., & Jansen, J. (1994). Global processing-time coefficients characterize individual and group differences in cognitive speed. *Psychological Science, 5*(6), 384-389.

Hale, S., Myerson, J., Rhee, S. H., Weiss, C. S., & Abrams, R. A. (1996). Selective interference with the maintenance of location information in working memory. *Neuropsychology, 10*(2), 228-240.

Halford, G. S. (1998). Development of processing capacity entails representing more complex relations: Implications for cognitive development. In R. H. Logie, & K. J. Gilhooly (Eds.), *Working memory and thinking* (pp. 139-157). Hove: Psychology Press.

Halford, G. S. (2000, October). *Analysis of complexity in human performances and decision making.* Workshop presented at the Annual Conference of the Australian Psychological Society, Canberra, Australia.

Halford, G. S., Birney, D. P., & Andrews, G. (2000). *Manual for computer administered relational complexity tasks*. Brisbane, Australia: Author.

Halford, G. S., Wilson, W. H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral and Brain Sciences, 21*(6), 803-831.

Harm, M., & Seidenberg, M. (1999). Reading acquisition, phonology, and dyslexia:

Insights from a connectionist model. *Psychological Review, 106,* 491-528.

Heath, S. M., Hogben, J. H., & Clark, C. D. (1999). Auditory temporal processing in disabled readers with and without oral language delay. *Journal of Child Psychology and Psychiatry, 40,* 637-647.

Hoffman, L. M. (2001). Visual information processing in children with and without language impairment. (Doctoral dissertation, University of Texas at Austin, 2000) *Dissertations Abstracts International, 61*(8-B), 4114.

Hohnen, B., & Stevenson, J. (1999). The structure of genetic influences on general cognitive, language, phonological, and reading abilities. *Developmental Psychology, 35*(2), 590-603.

Jensen, A. (1993). Why is reaction time correlated with psychometric *g*? *Current Directions in Psychological Science, 2,* 53-56.

Joanisse, M. F., Manis, F. R., Keating, P., & Seidenberg, M. S. (2000). Language deficits in dyslexic children: Speech perception, phonology, and morphology. *Journal of Experimental Child Psychology, 77*(1), 30-60.

Joanisse, M. F., & Seidenberg, M. S. (1998). Specific language impairment: A deficit in grammar or processing. *Trends in Cognitive Science, 2,* 240-247.

Johnston, J. R. (1991). The continuing relevance of cause: A reply to Leonard's "Specific Language Impairment as a Clinical Category". *Language, Speech, and Hearing Services in Schools, 22*, 75-79.

Johnston, J. R., & Ellis Weismer, S. (1983). Mental rotation abilities in language-disordered children. *Journal of Speech and Hearing Research, 26,* 397-403.

Jöreskog, K., & Sörbom, D. (2003). *LISREL* (Version 8.54) [Computer software and manual]. Chicago: Scientific Software International.

Jöreskog, K., & Sörbom, D. (2003b). *PRELIS* (Version 8.54) [Computer software and manual]. Chicago: Scientific Software International.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 98,* 122-149.

Kail, R. (1994). A method for studying the generalized slowing hypothesis in children with specific language impairment. *Journal of Speech and Hearing Research, 37*, 418-421.

Kail, R., & Hall, L. K. (2001). Distinguishing short-term memory from working memory. *Memory and Cognition, 29*(1), 1-9.

Kail, R., & Hall, L. K. (1994). Processing speed, naming speed, and reading. *Developmental Psychology, 30*(6), 949-954.

Kail, R., & Park, Y-S. (1992). Global developmental change in processing time. *Merrill-Palmer Quarterly, 38*(4), 525-541.

Kail, R., & Park, Y-S. (1994). Processing time, articulation time, and memory span. *Journal of Experimental Child Psychology, 57*, 281-291.

Kamhi, A. G. (1998). Trying to make sense of developmental language disorders. *Language, Speech and Hearing Services in Schools, 29*(1), 35-44.

Kelloway, E. K. (1998). *Using LISREL for structural equation modelling: A researcher's guide.* Thousand Oaks, CA: Sage.

Kolb, B., & Whishaw, I. Q. (1995). *Fundamentals of human neuropsychology (4th ed.).* London: Freeman Worth.

Kraus, N., McGee, T. J., Carrell, T. D., Zecker, S. G., Nicol, T. G., & Koch, D. B. (1996). Auditory neurophysiologic responses and discrimination deficits in children with learning problems. *Science, 273*, 971-973.

Lahey, M., & Edwards, J. (1995). Specific language impairment: Preliminary investigation of factors associated with family history and with patterns of language performance. *Journal of Speech and Hearing Research, 38*, 643-657.

Lahey, M., Edwards, J., & Munson, B. (2001). Is processing speed related to severity of language impairment. *Journal of Speech, Language, & Hearing Research, 44*(6), 1354-1361.

Law, J. (1992). Factors associated with language impairment. In J. Law (Ed.), *The early identification of language impairment in children* (pp. 41-62). London: Chapman & Hall.

Leonard, L. B. (1998). *Children with specific language impairment*. London: MIT Press.

Leonard, L. B. (1987). Is specific language impairment a useful construct? In S. Rosenberg (Ed), *Disorders of first-language development* (Vol. 1pp. 1-39). Cambridge: Cambridge University Press.

Leonard, L. B., Nippold, M. A., Kail, R., & Hale, C. A. (1983). Picture naming in language-impaired children. *Journal of Speech and Hearing Research, 26,* 609-615.

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modelling in psychological research. *Annual Review of Psychology, 51,* 201-226.

MacDonald, M. C., & Christiansen, M. H. (2002). Reassessing working memory: Comment on Just and Carpenter (1992) and Waters and Caplan (1996). *Psychological Review, 109*(1), 35-54.

Mackner, L.M., Black, M.M., & Starr, R.H.Jnr. (2003). Cognitive development of children in poverty with failure to thrive: A prospective study through age 6. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 44*(5), 743-751.

Macromedia, Inc. (1987-1997). SoundEdit™16 (Version 2.0.7) [Computer Software].

MacWhinney, B. (1998). Models of the emergence of language. *Annual Review of Psychology, 49,* 199-227.

Miller, C. A., Kail, R., Leonard, L. B., & Tomblin, J. B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech, Language, & Hearing Research, 44*(2), 416-433.

Miller, L. T., & Vernon, P. A. (1992). The general factor in short-term memory, intelligence, and reaction time. *Intelligence, 16,* 5-29.

Molfese, V.J., Modglin, A., Molfese, D.L. (2003). The role of environment in the development of reading skills: A longitudinal study of preschool and school-age measures. *Journal of Learning Disabilities, 36*(1), 59-67.

Montgomery, J. W. (1995). Examination of phonological working memory in specifically language-impaired children. *Applied Psycholinguistics, 16*, 355-378.

Montgomery, J. W. (2002). Understanding the language difficulties of children with specific language impairments: Does verbal working memory matter? *American Journal of Speech-Language Pathology, 11*(1), 77-91.

Nation, K., Adams, J. W., Bowyer-Crane, C. A., & Snowling, M. J. (1999). Working memory deficits in poor comprehenders reflect underlying language impairments. *Journal of Experimental Child Psychology, 73*, 139-158.

NCSS Statistical Software. (2000). *Power analysis and sample size* [Computer software]. Retrieved October 16, 2000 from http://www.ncss.com/pass.html

Nettelbeck, T., Edwards, C., Vreughdenhil, A. (1986). Inspection time and IQ: Evidence for a mental speed-ability association. *Personality and Individual Differences, 7,* 633--641.

Nettelbeck, T., & Lally, M. (1976). Inspection time and measured intelligence. *British Journal of Psychology, 67,* 17-22.

Noland, J.S., Singer, L.T., Arendt, R.E., Minnes, S., Short, E.J., & Bearer, C.F. (2003). Executive functioning in preschool-aged children prenatally exposed to alcohol, cocaine, and marijuana. *Alcoholism: Clinical and Experimental*

Research, 27(4), 647-656.

Patterson, K. E., Seidenberg, M., & McClelland, J. (1989). Dyslexia in a distributed, developmental model or word recognition. In R. Morris (Ed.), *Parallel distributed processing.* Oxford, England: Oxford University Press.

Pinker, S. (1991). Rules of language. *Science, 253*(5019), 530-535.

Plante, E. (1998). Criteria for SLI: The Stark and Tallal legacy and beyond. *Journal of Speech, Language, and Hearing Research, 41*(4), 951-957.

Raven, J. C. (1989). *Standard Progressive Matrices*. Melbourne, Victoria: Australian Council for Education Research Ltd.

Raven, J., Raven, J.C. & Court, J.H. (2000). *Manual for Raven's Progressive Matrices 2000 edition*. Oxford: Oxford Psychologists Press.

Roberts, J. E., & Hunter, L. (2002). Otitis media and children's language and learning. *The American Speech and Hearing Association Leader, October 8*, 6-7, 18.

Roberts, J. E., Burchinal, M. R., Zeisel, S. A. (2002). Otitis media in early childhood in relation to children's school-age language and academic skills. *Pediatrics, 110*(4), 696-706.

Roberts, J. E., Burchinal, M. R., Zeisel, S. A., Neebe, E. C., Hooper, S. R., Roush, J., Bryant, D., Mundy, M., & Henderson, F. (1998). Otitis media, the caregiving environment, and language and cognitive outcomes at 2 years. *Pediatrics, 102*(2), 346-354.

Saltaris, C., Serbin, L.A., Stack, D.M., Karp, J.A., Schwartzman, A.E., & Ledingham, J.E. (2004). Nurturing cognitive competence in preschoolers: A longitudinal study of intergenerational continuity and risk. *International Journal of Behavioural Development, 28*(2), 105-115.

Saracho, O.N. 92002). Family literacy: Exploring family practices. *Early Childhood Development & Care, 172*(2), 113-122.

Sattler, J. M. (1992). *Assessment of children* (3rd ed.). San Diego: Jerome M Sattler, Publisher Inc.

Savich, P. A. (1984). Anticipatory imagery ability in normal and language-disabled children. *Journal of Speech and Hearing, 27,* 494-501.

Schuele, C. M. (2001). Socio-economic influences on children's language acquisition. Journal of Speech-Language Pathology and Audiology, 25(2), 77-88.

Seidenberg, M. S. (1997). Language acquisition and use: Learning and applying probabilistic constraints. *Science, 275*, 1599-1603.

Semel, E., Wiig, E. H., & Secord, W. A. (1995). *The Clinical Evaluation of Language Fundamentals (3rd ed.).* San Antonio: Harcourt Brace.

Simkin, Z., & Conti-Ramsden, G. (2001). Non-word repetition and grammatical morphology: normative data for children in their final year of primary school. *International Journal of Language and Communication Disorders, 36*(3), 395-404.

Sininger, Y. S., Klatzky, R. L., & Kirchner, D. M. (1989). Memory scanning speed in language-disordered children. *Journal of Speech and Hearing Research, 32*, 289-297.

St. John, M., & Gernsbacher, M. A. (1998). Learning and losing syntax: Practice makes perfect and frequency builds fortitude. In A. F. Healy & L. E. Bourne Jr. (Eds.), *Foreign language learning: Psycholinguistic experiments on training and retention* (pp. 231-255). Mahwah, NJ: Erlbaum.

Stanton-Chapman, T. L., Chapman, D. A., Bainbridge, N. L., & Scott, K. G. (2002). Identification of early risk factors for language impairment. *Research in Developmental Disabilities, 23*(6), 390-405.

Stark, R. E., & Heinz, J. (1996). Vowel perception in children with and without language impairment. *Journal of Speech and Hearing Research, 39*, 860-869.

Stark, R. E., & Tallal, P. (1981). Selection of children with specific language deficits. *Journal of Speech and Hearing Disorders, 46*(2), 114-122.

STAZ Software, Inc. (1999). FutureBASIC[3] [Computer Software]. Diamondhead, MS: Author.

Strathearn, L. (2003). Long-term cognitive function in very low-birth-weight infants. *Journal of the American Medical Association, 289*(17), 2209.

Stromsworld, K. (1998). Genetics of spoken language disorders. *Human Biology, 70*(2), 297-324.

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics (4th ed).* Boston: Allyn and Bacon.

Tallal, P. (1980). Language disabilities in children: A perceptual or linguistic deficit? *Journal of Pediatric Psychology, 5*(2), 127-140.

Tallal, P. (1999). Children with language impairment can be accurately identified using temporal processing measures: A response to Zhang and Tomblin, *Brain and Language*, **65**, 395-403 (1998). *Brain and Language, 69*, 222-229.

Tallal, P., Miller, S. L., Jenkins, W. M., & Merzenich, M. M. (1997). The role of temporal processing in developmental language-based learning disorders: Research and clinical implications. In B. Blachman (Ed), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 49-66). New Jersey: Lawrence Erlbaum Associates.

Tallal, P., & Piercy, M. (1973). Developmental aphasia: Impaired rate of non-verbal processing as a function of sensory modality. *Neuropsychologia, 11*, 389-398.

Tallal, P., & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologia, 12*, 83-93.

Tallal, P., & Piercy, M. (1975). Developmental aphasia: The perception of brief vowels and extended stop consonants. *Neuropsychologia, 13*, 69-74.

Tallal, P., Stark, R., & Curtiss, B. (1976). Relation between speech perception and speech production impairment in children with developmental dysphasia. *Brain and Language, 3*, 305-317.

Tallal, P., Stark, R., Kallman, C., & Mellits, D. (1981). A reexamination of some nonverbal perceptual abilities of language-impaired and normal children as a function of age and sensory modality. *Journal of Speech and Hearing Research, 24*(3), 351-357.

Tallal, P., Stark, R. E., & Mellits, D. E. (1985). Identification of language-impaired children on the basis of rapid perception and production skills. *Brain and Language, 25,* 314-322.

The Psychological Corporation. (1995). *Clinical Evaluation of Language Fundamentals (3rd ed.).* San Antonio: Harcourt Brace.

Tomblin, J. B., Records, N. J., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research, 40*(6), 1245-1260.

Vance, M. (2001). *Speech processing and short-term memory in children with normal and atypical speech & language development.* Unpublished PhD thesis. University College London.

van der Lely, H. K. J., & Howard, D. (1993). Children with specific language impairment: Linguistic impairment or short-term memory deficit? *Journal of Speech and Hearing Research, 36*(6), 1193-1207.

Vanderplas, J. M., & Garvin, E. A. (1959). The association value of random shapes. *Journal of Experimental Psychology, 57*(3), 147-154.

Vernon, P. A., & Kantor, L. (1986). Reaction time correlations with intelligence test scores obtained under either timed or untimed conditions. *Intelligence, 10,* 315-330.

Vernon, P. A., Nador, S., & Kantor, L. (1985). Reaction times and speed-of-processing: Their relationship to timed and untimed measures of intelligence. *Intelligence, 9,* 357-374.

Votruba-Drzal, E. (2003). Income changes and cognitive stimulation in young children's home learning environments. *Journal of Marriage and Family, 65*(2), 341-355.

Waber, D. P., Weiler, M. D., Bellinger, D. C., Marcus, D. J., Forbes, P. W., Wypij, D., Wolff, P. H. (2000). Diminished motor timing control in children referred for diagnosis of learning problems. *Developmental Neuropsychology, 17,* 181-197.

Waber, D. P., Weiler, M. D., Wolff, P. H., Bellinger, D., Marcus, D. J., Arial, R., Forbes, P., Wypij, D. (2001). Processing of rapid auditory stimuli in school-age children referred for evaluation of learning disorders. *Child Development, 72,* 37-49.

Waters, G. S., & Caplan, D. (1996). The capacity theory of sentence comprehension: A critique of Just and Carpenter (1992). *Psychological Review, 103,* 761-722.

Wechsler, D. (1992). *Wechsler Intelligence Scale for Children - 3rd edition manual - Australian adaptation*. San Antonio: Harcourt Brace Jovanovich.

Wiig, E. H., Zureich, P., & Chan, H-N. H. (2000). A clinical rationale for assessing rapid automatized naming in children with language disorders. *Journal of Learning Disabilities, 33*(4), 359-374.

Wolf, M. (1997). A provisional, integrative account of phonological and naming-speed deficits in dyslexia: Implications for diagnosis and intervention. In B. Blachman (Ed), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 67-92). New Jersey: Lawrence Erlbaum Associates.

Wolff, P. H. (2002). Timing precision and rhythm in developmental dyslexia. *Reading & Writing, 15,* 179-206.

Wright, B. A., Lombardino, L. J., King, W. M., Puranik, C. S., Leonard, C. M., & Merzenich, M. M. (1997). Deficits in auditory temporal processing and spectral resolution in language-impaired children. *Nature, 387*(6629), 176-178.

Yoshinaga-Itano, C., Sedey, A. L., Coulter, D. K., & Mehl, A. L. (1996). Language of early - and later - identified children with hearing loss. *Pediatrics, 102*(5), 1161-1171.

Appendix A

Ethical Approval and Participant Consent Documents

JAMES COOK UNIVERSITY
ETHICS REVIEW COMMITTEE
(Human Ethics Sub-Committee)

APPROVAL FOR RESEARCH OR TEACHING INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR	*Katrina Ann Lines*
SCHOOL	*Psychology*
PROJECT TITLE	***Factors Affecting Children's Language Learning***

DATE	*5 February 2001 – 30 March 2003*	**CATEGORY**	*2*

This project has been allocated Ethics Approval Number with the following provisos and reservations: **H1144**

1. All subsequent records and correspondence relating to this project must refer to this number.

2. The Principal Investigator is to advise the responsible Monitor appointed by the Ethics Review Committee:
   - periodically of the progress of the project;
   - when the project is completed or if suspended or prematurely terminated for any reason.

3. In compliance with the National Health and Medical Research Council (NHMRC) ***"National Statement on Ethical Conduct in Research Involving Humans"*** you are required to provide an annual report detailing security of records and compliance with conditions of approval. The report should very briefly summarise progress.

NAME OF RESPONSIBLE MONITOR	*Dr David Mitchell*
SCHOOL	*Psychology*

[forwarded by E-mail without signature]

Tanya Fisher
Ethics Administrator
Ph: 4781 4342
Fax: 4781 5521
E-mail: Tanya.Fisher@jcu.edu.au

DATE *Wednesday, 13 December 2000*

Principal Investigator Ethics Number: **E1459**
*Ref:_APPROVALS\Human\2000\12_00**H1144***

JAMES COOK UNIVERSITY
P.O. Box 6811, Cairns Q 4870
School of Psychology
Ph: 4042 1206
Fax: 4042 1390

CHILDREN'S LANGUAGE ABILITY STUDY

Dear Parents and Guardians,

You and your child are invited to take part in a study on the important factors that help children's language learning. Some children do not learn language as easily or as well as others and may need extra help before and during their school years. There are a number of ideas about why this happens, such as health and memory problems. This study will look at language ability and a number of these areas. It is important that the study includes children *with* and *without* language or learning problems. This will show the areas that are important for language learning and how they may be affecting children who have problems.

This study is part of my PhD. degree in psychology at James Cook University, Cairns Campus. Your child's class was chosen randomly from all the State primary school Grade 3 classes in the Cairns area. The study will involve eight other Grade 3 classes in the Cairns area as well.

If you take part in the project you will help provide useful information about children's language ability and language problems. All Grade 3 children from the classes chosen and their parents or guardians are eligible to take part. If you agree to be involved your child will go to two one-hour sessions during school hours. At these sessions the children spend time playing special computer games, doing puzzles and taking a language test. Some of the puzzles and the language test are like things they may have already done at school. Children think these sessions are fun and get to choose some stickers as a thank you for taking part.

The study also needs a parent or guardian to participate, as you will know all the important developmental history of your child, like whether they were born prematurely and how old they were when they started talking and walking. I will ask you about this information when I call to give you your child's results. You choose the best time and day for this call to take place.

Taking part in this study is strictly your decision and if you do decide, you will be able to stop at any time. No results from this study will be used with any information that could identify your child or family.

Your school will be given a report of the overall results of the class. If I identify any children who have problems (language or otherwise), I will tell their parents straight away. I will be able to provide information about who to see at the school and other places to get help if that is what the parents would like. I am not offering therapy for language or other problems as part of participation in this research.

Please consent for yourself and your child to participate in this study. The information learned will help children with language problems and all children by giving information about what is important for language learning and ways to teach language and literacy. If you have any questions about taking part in the study please ring me on the numbers below.

If you would like to take part in the study **please fill out and sign the consent form** that your child brought home with this letter and **send the signed form back to school as soon as possible**. Thank you for your time.
Katrina Lines

JAMES COOK UNIVERSITY

CHILDREN'S LANGUAGE ABILITY STUDY
INFORMED CONSENT FORM

This study is about the relationship between language ability and a number of things that can affect it such as developmental history, health, memory and the capacity to process sounds that occur close together in time. There are no foreseeable risks with this research, however, if any uneasiness or discomfort should occur as a result of your child's or your own participation, then you can contact the principal researcher to ask questions, discuss feelings or withdraw from the study. Contact details are provided below.

CONSENT

I consent to participate and give consent for my child to participate in the research project on children's language ability and I understand that:

1. The aims of this study have been clearly explained to me and I understand what is wanted of me and my child. I have been given an information letter, a copy of the consent form and the chief researcher's contact details.

2. My child will be asked to complete two 1-hour testing sessions during school hours at a time chosen by his or her teacher.

3. These sessions involve tasks and activities that are not harmful to my child, but are similar to some that he or she may have already done at school.

4. I will be asked to provide non-intrusive information about my child's health, developmental, language and schooling history and some background information about our family.

5. Our participation is entirely voluntary, and I may stop my child's and my own participation in the research project at any time without penalty or censure.

6. All information collected about me, my child and our family will be confidential and kept in a locked cabinet. No individual data will be reported, and data, after final collection will be coded so that the participants cannot be identified.

7. I will be provided with a personal report about my child's results after data collection and analysis. This will take place in a telephone call to me by the principal researcher at a time of my choosing, and will be combined with the interview for health and developmental information about my child.

8. I will be notified of any problem identified during testing of my child. I understand that therapy for language or other problems is not offered as part of participation in this research, but that I will be provided with names and contact details of people who can help my child if I wish.

9. No information about my child, our family, or myself will be disclosed to anyone without my approval.

10. I give permission for data collected during this study to be published as part of the principal researcher's doctoral thesis, peer review journal articles and in a report to Education Queensland, as long as there is no identifying information about my child, our family or myself in these publications.

Name: *(print please)*…………………………………………………………………….……	
Child's Name: ……………………………………**Child's Date of Birth……/……./……..**	
Your Relationship to Child: …………………………….…………………….…………………	
Telephone Contact: ………………………………………..…………………….…………	
Best day to ring with feedback on your child's results:	
Mon Tues Wed Thu Fri Sat Sun *(please circle one or more days)*	
Best time of day to ring with feedback on your child's results: ……………….……am / pm	
Signature:	**Date:**

WITNESSED BY:

Name: *(print please)*………………………………………………………………………	
Signature:	**Date:**

Cut this section off for your records. You will be given a copy of the signed consent form.

CHILDREN'S LANGUAGE ABILITY STUDY – JAMES COOK UNIVERSITY, CAIRNS

RESEARCHER CONTACT DETAILS:

Katrina Lines, PhD Candidate
School of Psychology
James Cook University, Cairns Campus
PO BOX 6811, CAIRNS Q 4870
Ph: 4042 1477

Appendix B

RESEARCH INSTRUCTION MANUAL

Contents

Contents	**223**
General Testing Information	**224**
General Instructions	**224**
Equipment in Research Box	**225**
Testing Procedure	**226**
Equipment Needed for Tests and Tasks	**226**
Clinical Evaluation of Language Fundamentals – III (CELF-3)	**226**
Testing Information	**226**
Sentence Structure Subtest	**227**
Word Structure Subtest	**228**
Concepts and Directions Subtest	**230**
Formulated Sentences Subtest	**232**
Word Classes Subtest	**234**
Recalling Sentences Subtest	**236**
Rapid Automatic Naming Subtest (for Processing Speed)	**237**
Raven's Standard Progressive Matrices	**240**
Global Processing Speed	**242**
Arrow Task	**242**
Sternberg Tasks	**243**
Word Search	**244**
Figure Search	**245**
Memory	**247**
Span Tasks	**248**
Digit Span	**248**
Spatial Span	**249**
Nonword Repetition Task	**251**
Cognitive Complexity	**251**
N-Term	**251**
Latin Square	**253**
Auditory Repetition Task	**257**

General Testing Information

General Instructions

1. Visitors to most schools have to sign in and out. The sign in book is usually at the school administration office.

2. Children are usually not allowed to walk around a school on their own – they most often travel in twos and threes. We may have to escort them to and from their class.

3. Some schools have a policy that no child will be alone one-on-one with an adult.

4. We will try to disrupt the class and school as little as possible.

5. All participating children's names, identifying information and test score/performance will remain **strictly confidential**.

6. No scores or test results can be discussed with anyone (including teachers and principals) other than the child and their parents, unless the parents give written permission otherwise.

7. All test results will remain in a closed folder in the research box, which will be the responsibility of the principal researcher.

8. Score forms, tapes and disks will be removed daily and stored elsewhere in a locked filing cabinet.

9. There will be forms for each school with the child's first name and ID number for recording what tasks they have completed, in what order and on what date.

10. Most of the computerised tasks save data automatically, this book tells you what to do if they don't. Data that is saved automatically will be backed up onto a floppy disk at the end of each session.

11. The participating child can stop or rest at any time if they wish.

12. The children will be thanked and offered some stickers and stamps after they have finished their session.

Equipment contained in the research box:

6. Batteries, headphones, tapes and disks
7. Stopwatch, voice recorder
8. Pens, pencils, stapler, clipboards, notebook etc.
9. CELF-3 record forms and stimulus manuals
10. SPM record forms and stimulus book
11. Research procedure and instruction manuals
12. Participant Checklist (records what children have completed etc)
13. Completed forms
14. Stickers and stampers, cups

Testing Procedure

One half of the participants in each class will begin with the clinical session whilst the other half begin with the computerised tasks session.

In each testing session, the order that tasks are run in will be counterbalanced for each two children that participate. This will be recorded on the participant checklist. The order of the tasks is on the checklist. Indicate which order the child completed them in, so that the next child receives the reverse order.

The order for the (mostly) clinical session is:

1. The Clinical Evaluation of Language Fundamentals – III (CELF-III)
2. Raven's Standard Progressive Matrices (SPM)
3. Nonword Repetition Task (NRT)
4. Arrow Task
5. Auditory Temporal Processing

The order is reversed for every second child.

The order for the computerised tasks session is:

Latin Square
Word Task
Digit Span
Spatial Span
Figure Task
N-Term

The order is reversed for every second child.

Equipment necessary for the tests and tasks are as follows:

- **CELF-III**: test stimuli books 1 and 2, record form, stopwatch and the instruction book.
- **Raven's SPM**: test booklet and a record form.
- **NRT**: the Macintosh computer and the voice recorder with tape inserted.
- **Latin Square**: the Dell laptop.
- **N-Term**: the Dell laptop.
- **Arrow Task**: the Macintosh computer and the button box.
- **Sternberg Tasks**: the Macintosh computer and the button box.
- **Span Tasks**: the Macintosh computer, a keyboard and the other monitor.
- **Auditory Temporal Processing**: the Macintosh computer, headphones and button box.

INSTRUCTIONS FOR PUBLISHED TESTS
(as they appear in the manual)

Clinical Evaluation of Language Fundamentals – III

Receptive Subtests:	Sentence Structure
Age 6 - 8	Concepts and Directions
	Word Classes
Expressive Subtests:	Word Structure
Age 6 - 8	Formulated Sentences
	Recalling Sentences
Processing Speed:	Rapid Automatized Naming – *Need Stopwatch*

Give subtests in the order they appear in the record booklet. The record booklet gives good instructions for each test, including discontinue rules (if applicable) and stimulus materials required.

You will administer tests from pages 2 – 7, and the RAN subtest on page 14, ignore all other subtests in the record booklet.

Record the child's ID number and the school on the front of the form.

Set up seating arrangements so that you are sitting next to the child, or at right angles to them. If you are right handed sit on their right side and vice versa if you are left handed.

Place the stimulus material in front of the child, but make sure you can see it and reach it to point and turn pages.

Have the record form on the clipboard on your knee, along with the stopwatch and other items you may need.

Place completed record forms in the appropriate folder in the research box.

SUBTESTS

1. SENTENCE STRUCTURE (SS) – Page 2 of the Record Form

Picture Stimuli: Stimulus Manual 1
Start: Item 1
Repetitions: No repetitions allowed
Discontinue: None – administer all items
Stimulus Picture Identification is as follows:

A	**B**
C	**D**

DO: *Open Stimulus Manual 1 and set it up at the first page of the Sentence Structure subtest.*

Trial 1

SAY: Let's look at these pictures. I am going to point to the picture that shows, 'the boy has a dog'.
DO: *Point to the correct picture B.*
SAY: Now you point to the picture that shows, 'the boy has a ball'.

DO: *If the child requests a repetition, responds incorrectly or does not respond within 10 seconds….*

SAY: Point to, "the boy has a ball".

DO: *If the child still does not respond, or responds incorrectly..*

SAY: Here is, "the boy has a ball", and..

DO: *Point to picture C and proceed to the second trial item.*

Trial 2

DO: *Turn to the stimulus page for Trial 2.*

SAY: Now point to, "the girl lost her balloon".

DO: *If the child requests a repetition, responds incorrectly, or does not respond within 10 secs, repeat..*

SAY: Point to, "the girl lost her balloon".

DO: If the child still does not respond correctly…

SAY: Here is, "the girl lost her balloon"…

DO: *And point to picture A.*

Proceed to Test Items

SAY: Now let's do some more. Listen carefully, because I can only say it once.

DO: For each item, turn to the appropriate stimulus page. Do not repeat any items. Turn to Page 2 of the record form to present items and record responses to this subtest.

SAY: Point to, (*get each item sentence from record form*).

SCORING: Circle the child's response (A,B,C,or D) on the record form for each item.

2. WORD STRUCTURE (WS) – Page 2 of the Record Form
Picture Stimuli: Stimulus Manual 1

Start Point: Item 1
Repetitions: One repetition is allowed
Discontinue Rule: None- administer all items.
Stimulus Picture Identification: Top to bottom of the page. The page may contain several items, including trial and demonstration items.

Trial 1

Page WS T1, T2, T3 in Stimulus Manual.

SAY: I'm going to show you some pictures and say some things about them. I want you to help me by finishing some of the things I say. Let's try one. Here is a boy.

DO: *Point to the picture of the boy.*

SAY: and here is a ……..(pause and wait for the child to answer).

DO: *If the child does not respond or responds incorrectly…*

SAY: I want you to say the word "girl" to finish what I was saying.

Trial 2

Same page.

SAY: Here is one bus.

DO: *Point to the bus.*

SAY: and here are two……(point and pause).
DO: *The child should say buses. If the child responds correctly, proceed to the third trial item. If the child responds incorrectly, requests a repetition, or hesitates for more than 10 secs, repeat the item by saying*

SAY: Here is one bus, and here are two…….(pause).

DO: *If the child still does not respond, or responds incorrectly…*

SAY: I want you to say the word "buses" to finish what I was saying.

Trial 3

Same page.

SAY: Lee said, those shoes are yours, and these shoes are…….(pause).

DO: *The child should say "mine". If the response is correct proceed to the test items.*

If the response is incorrect, a repetition is requested, or the child hesitates for more than 10 secs, repeat the item. If the child still does not respond or responds incorrectly..

SAY: I want you to say the word "mine" to finish what I was saying.

DO: *Proceed to the test items.*

Test Items

Check each page for which items are contained on it. For example, the next page WS Picture A, D, 1, 2 is Section A, a demonstration item and the first two test items.

SAY: Now let's try some more. Remember, listen to what I say about the picture and help me finish what I say about each one. If you need it, I can repeat each one once.

DO: *Present each test item in turn from the Record Form, following closely the pages in the stimulus manual.*

As you read the parts of each item, point to the appropriate sections of the stimulus page.

Since the picture format used to present items 23 – 26 is different to that used to present items 1 –22, directions for pointing to the stimulus items are also included in the record form.

If the child is distracted by the other pictures on the page, even with you pointing, use a blank sheet of paper to cover the other item pictures on the stimulus manual page.

Do not repeat an item if the student responds incorrectly.

SCORING: Record the child's response verbatim on the form.

3. CONCEPTS AND DIRECTIONS (CD) – Page 4 of the Record Form

Picture Stimuli: Stimulus Manual 2

Start: Item 1 (Ages 6-8)

Repetitions: None allowed.

Discontinue: Discontinue testing after errors or no response on five consecutive items.

Wait until you are CERTAIN the child has completed his or her response before presenting the next item.

Familiarisation 1

Page CD F1 in the stimulus manual.

SAY: I am going to point to some shapes. I will tell you which ones. Point to the circle (*point*), point to the square (*point*), and point to the triangle (*point*). I pointed to them in the same order I said them.

Familiarisation 2

SAY: Now I am going to show you some more shapes. This time, I will ask YOU to point to some of the shapes. I will say GO when I want you to point.

DO: *Turn to page CD F2.*

SAY: Point to the black circle. GO.

DO: *Pause for the response.*

SAY: Now let's do it again. This time point to the shapes in the order I tell you. Point to the white square and the black triangle. GO.

DO: *Pause for response.*

If the student responds correctly, proceed to Trial 1.

If the student requests a repetition, responds incorrectly, or does not respond within 10 secs ..

SAY: Listen carefully. Point to the white square and the black triangle. GO.

DO: *If the student still does not respond correctly within 10 secs..*

SAY: Here is the black circle (*point*). Here is the white square (*point*).

Trial 1

DO: *Turn to page CD T1*

SAY: Now let's try some more. Point to the white square and a black circle. GO.

DO: *Pause for a response.*

If the student responds correctly, proceed to Trial 2.

If the student requests a repetition, responds incorrectly, or does not respond within 10 secs, repeat Trial 1.

If necessary, remind the child to point to the shapes in the order mentioned, and not to point until you say GO.

If the student still does not respond correctly within 10 secs after the repetition, proceed to Trial 2.

Trial 2

DO: *Turn to CD T2*

SAY: Point to the black triangle, point to the white triangle. GO.

DO: *Pause for a response.*

If necessary, repeat the second trial item, reminding the student to point to the shapes in the order mentioned and not to point until you say GO.

Test Items

SAY: Now let's try some more. Remember to point to the shapes in the order I tell you. Do not point until I say GO. Listen carefully, because I can only say them one time.

DO: *Turn to each test item page, read the entire item and say GO. Pause for a response. When you are certain the child is finished proceed to the next item.*

SCORING: Circle 1 if they respond correctly, and 0 for an incorrect response. If the child does not respond, or says something like "I don't know", or "I can't do it", circle NR for non-response. Discontinue testing when five consecutive errors or non-responses occur.

4. FORMULATED SENTENCES (FS) – Page 5 in the Record Form

Picture Stimuli: Stimulus Manual 1 (flip side)

Start: Item 1

Repetitions: One repetition allowed

Discontinue: Discontinue testing after 0 scores (unacceptable sentences or no response) on five consecutive items.

Trial 1

DO: *Turn to page FS T1.*

SAY: Here is a picture of a family. I will use the word "book" in a sentence to talk about this picture. (pause) "The woman is reading a book". Or I could say, " That book is on the floor".

Trial 2

DO: *Turn to page FS T2.*

SAY: Here is another picture. Now you make a sentence about this picture using the word "playing". You must make your sentence about something in the picture and you must use the word "playing". Look at the picture to help you think of what to say.

DO: *If the student produces a phrase or sentence that is appropriate to the context of the stimulus picture and incorporates the stimulus word, proceed to the third trial item.*

If the student hesitates, requests a repetition, or produces a phrase or sentence that does not include stimulus word or is not appropriate to the stimulus picture, repeat the item and…

SAY: Remember, make a sentence about the picture and use the word "playing".

DO: *If the student still does not respond with the stimulus word in the appropriate context…*

SAY: You could have said………....(Give a sample sentence).

DO: *Proceed to Trial 3.*

Trial 3

DO: *Turn to page FS T3.*

SAY: Here is another picture. Now you make a sentence about this picture using the word "when". You must make your sentence about something in the picture and you must use the word "when". Look at the picture to help you think of what to say.

DO: *If the student produces a phrase or sentence that is appropriate to the context of the stimulus picture and incorporates the stimulus word, proceed to the third trial item.*

If the student hesitates, requests a repetition, or produces a phrase or sentence that does not include stimulus word or is not appropriate to the stimulus picture, repeat the item and…

SAY: Remember, make a sentence about the picture and use the word "when".

DO: *If the student still does not respond with the stimulus word in the appropriate context…*

SAY: You could have said………....(Give a sample sentence).

DO: *Proceed to Test Items*

Test Items

SAY: Now I will say some more words and show you some more pictures. I want you to tell me a sentence for each word I say. You must make your sentence about the picture and use the word I tell you in your sentence. If you need it, I can repeat each one once.

DO: *Present the pictures in the Stimulus Manual. You may repeat each item one time if the child does not respond within 10 secs or requests a repetition. Note that there are new directions for the student before Item 20.*

SCORING: Record responses verbatim. Score NR if the student makes no response or responds with "I don't know" or a similar reply. (See examiner's manual pgs 32 – 51 for scoring rules, but do not score as you go).

5. WORD CLASSES (WC) – Page 6 in the Record Form

Picture Stimuli: None

Start: Item 1 (ages 6-8)

Repetitions: None allowed

Discontinue: Discontinue testing after 0 scores (errors or no response) on five consecutive items.

There are two sets of trials in WC: Trial items 1-3 (for items 1-10) are at the beginning of the subtest and trial items 4-6 (for items 11-34) follow item 10. Use the same procedures to present both sets of trials.

Trial 1

SAY: I am going to read some words to you. Two of the words go together. Listen to the words and tell me the two that go together the best. (pause) "fast, wet, quick"

DO: *If the students responds by identifying the words "fast" and "quick" proceed to the second trial item.*

If the student requests a repetition, does not respond within 10 secs, or identifies two unrelated words..

SAY: Listen carefully to the words I say: "fast, wet, quick". Two of them go together best. They are "fast" and "quick".

DO: *Proceed to Trial 2.*

Trial 2

SAY: Now listen to some more words. Remember you are to tell me the two that go together best: (pause) "round, little, big".

DO: If the student identifies the words "little" and "big", proceed to the next trial item.

If the student requests a repetition, does not respond within 10 secs, or identifies an unrelated word pair, repeat the item..

SAY: Listen to the words again and tell me the two that go together best: (pause).."round, little, big".

DO: If the student still does not respond correctly…

SAY: The two words that go together best are "little" and "big".

DO: Proceed to the next trial item.

Trial 3

SAY: Listen and tell me the words that go together best: (pause).."whisker, cat, rock".

DO: *If the student identifies the words "whisker" and "cat", proceed to the next trial item.*

If the student requests a repetition, does not respond within 10 secs, or identifies an unrelated word pair, repeat the item..

SAY: Listen to the words again and tell me the two that go together best: (pause).."whisker, cat, rock".

DO: *If the student still does not respond correctly…*

SAY: The two words that go together best are "whisker" and "cat".

DO: Proceed to the test items.
Test Items

SAY: Now I will read some more words. Listen carefully to each set of three words and tell me the two words that go together best. Pay attention because I can only say them one time.

DO: *Read the items from the record form. If necessary, start each item with "LISTEN" to focus the child's attention on the new list. Do not repeat* *any items. There is a change of directions and three more trial items after item 10.*

Trials 4 – 6

DO: *Read instructions from the record form. If the student responds correctly present the remaining trial and test items.*

If the student does not respond correctly etc., repeat Trial 4. If the student still does not respond correctly, provide the correct words.

Repeat this process for remaining trial items then proceed to the remaining test items.

SCORING: Circle the words the student chooses. No response, or something similar to "I don't know " gets NR.

6. RECALLING SENTENCES (RS) – Page 6 in the Record Form

Picture Stimuli: None

Start: Item 1 (ages 6-8)

Repetitions: None allowed

Discontinue: Discontinue testing after three consecutive 0 scores (no responses or sentences with four or more errors).

Trial 1

SAY: Now I am going to say some things to you. I want you to listen carefully and repeat exactly what I say. If I say, "my sister is in the sixth grade", you repeat it as I say it. Let's try… "My sister is in the sixth grade".

DO: *If the child repeats the trial* **verbatim** *proceed to Trial 2.*

If the student does not respond within 10 secs or requests a repetition…

SAY: Let's try again. Listen carefully, and say exactly what I say. "My sister is in the sixth grade".

DO: *If the student still does not respond….*

SAY: You need to say, "My sister is in the sixth grade".

Trial 2

SAY: Listen to another sentence and say exactly what I say. (pause). " Does Mr Lopez teach reading?"

DO: *If the student repeats the trial **verbatim** proceed to the test items.*

If the student responds as if answering a question (i.e. yes, no, or I don't know Mr Lopez) explain that he or she needs to repeat the sentence not answer the question.

Repeat the item.

If the student does not repeat the item accurately on the second presentation, does not respond within 10 secs or requests a repetition…

SAY: Let's try again. Listen carefully and say exactly what I say. (pause) "Does Mr Lopez teach reading?"

DO: *If the student still does not respond…*

SAY: You need to say, "Does Mr Lopez teach reading?"

DO: *Proceed to the test items.*

Test Items

SAY: Now let's try some more. Remember to listen carefully and say exactly what I say, because I can only say it one time.

DO: *Read the test items at a normal conversational rate and in the sequence listed in the record form.*

SCORING: Edit the printed responses in the manner shown on the record form, or record the child's response verbatim. Circle NR if the child does not respond, or responds with a variation of "I don't know" etc.

7. RAPID AUTOMATIC NAMING (RAN) – Page 14 of the Record Form

Picture Stimuli: Stimulus Manual 1
Start: Item 1
Repetitions: None allowed
Discontinue: None – all items must be administered
Special Considerations: Do not administer to a child with fluency difficulties or fluency disorders or is colour blind. Discontinue administration if the child is unable to complete the first or second practice items.

There are 3 practice items to familiarise the student with the stimuli and the responses required. You may present each practice item twice if necessary.

Practice Item 1
Colour Naming

DO: *Turn to page RAN, P1, P2*

SAY: Here are some coloured circles. Listen to me as I name some of the colours.

DO: *Point to the first row (labelled Examiner on the record form) and name the colours.*

SAY: Tell me each of these colours.

DO: *Point to the row labelled student (row under the examiner's). If the student names the colours correctly, proceed to Practice 2.*

If the student does not name the colours correctly, present practice 1 again…

SAY: Let's try again. Listen as I tell you these colours again.

DO: *Point to each colour as you name it.*

SAY: Now you tell me these colours.

DO: If the student does not name the colours correctly on the second presentation of Practice 1, discontinue testing and indicate this in the record form.

Practice 2
Shape Naming

SAY: Here are some shapes. Listen as I name some of the shapes.

DO: *Point to the third row (labelled examiner on the record form) and name the shapes.*

SAY: Tell me these shapes.

DO: *Point to the fourth row.*

If the student names the shapes in the fourth row correctly proceed to Practice 3.

If the student does not name the shapes correctly, repeat the second practice item.

SAY: Let's try again. Listen as I name these shapes.

DO: *Point to each shape as you name it.*

SAY: Now you tell me these shapes.

DO: If the student does not name the shapes correctly on the second presentation of Practice 1, discontinue testing and indicate this in the record form.

Practice 3
Colour-Shape Naming

DO: *Turn to RAN P3.*

SAY: This page has different colours and shapes. Listen as I tell you the colour and shape of some of them.

DO: *Point to the first row and name the colour and shape of each (labelled examiner in the record form). Point to the next row…*

SAY: Tell me the colour and shape of each one in these two rows (point).

DO: *If the student names the colour-shape combinations correctly, proceed to the test items.*

If the student hesitates in naming the colour-shape combinations, ask the student to name the items with you.

SAY: Let's try saying the colours and shapes together.

DO: *Name the items in the first row with the child. Then repeat Practice 3*

SAY: Let's try this page again. Listen to me as I tell you the colours and shapes in the first row.

DO: *If the student names the colour-shape combinations correctly, proceed to the test items.*

If the student does not name them correctly, but has completed the first two practice items, then proceed to the Test Items.

Test Items

DO: *Turn to the relevant page.*

SAY: I am going to show you some more pages. This time, I will time you while you name the colours, the shapes and the colours and shapes on each page.

DO: *Read the instructions in each item from the record form.*

Do not point to the objects on the test page to prompt the child, although the child may do this him or herself.

Start timing when the student names the first object (colour, shape, or colour-shape) in each item. Stop timing when the student names the last object in each item. Present items 2 and 3 in sequence.

SCORING: Record student's error responses and the time needed to complete each item. As students will be responding rapidly, scoring error responses may be difficult. Draw a line through omitted or substituted words. Use a ruler or a blank piece of paper as a guide as you follow through the list. Tick where words have been added to a series. Alternately, tape record responses for later scoring.

Raven's Standard Progressive Matrices

You need the test booklet (stimulus material) and an answer sheet for each child. Place completed answer sheets in the appropriate file.

DO: *Record the child's first name, ID number and school on the answer sheet.*

SAY: These are all puzzles with pieces missing.

Open the booklet at the first problem A1, point to the top part of the figure.

SAY**:** The top part is a pattern with a bit cut out of it. Each of these pieces below is the right shape to fill the space, but only one of them is the right pattern.

DO: *Point to the pieces in turn*.

Number 1 is the right shape, but is not the right pattern. Number 2 is not a pattern at all. Number 3 is quite wrong. Number 6 is nearly right, but is wrong here.

DO: *Point to the white piece in Number 6*.

SAY: Only one is right in both ways. You point to the piece which is correct to finish the pattern.

DO: If the child does not point to the right piece, continue your explanation until the nature of the problem is clearly grasped and they point to the right piece.

SAY: Number 4 is the right bit isn't it? So the answer is Number 4.

DO: Turn to Problem A2

SAY: Now, you can do one on your own. Point to the piece which goes in here.

DO: *If the child does not choose the right piece, re-demonstrate Problem A1, and then come back to A2 and request an answer.*

If the problem is solved correctly, turn to Problem A3 and proceed as before.

At Problem A4, before the child has time to point to one of the pieces…..

SAY: Look carefully at these pieces.

DO: *Move your fingers across them.*

SAY: Only one of these pieces is right to complete the pattern. Be careful. Look at each of the six pieces first.

DO: *Point to each of the six pieces.*

SAY: Now you point to the right one to go in here.

DO: *Point to the space in the upper figure.*

When the child has pointed to one of the pieces, whether it is right or not….

SAY: Is that the right one to go in here?

DO: If the child says "yes", accept the choice with approval, whether right or wrong. If he or she wishes to change the choice….

SAY: All right. Well, point to the one that is right.

DO: *Whether the answer is right or wrong again…..*

SAY: Is that the right one?

DO: *If the child is satisfied, whether the choice is right or wrong, accept that choice, but if there still seems to be doubt….*

SAY: Well, which do you really think is the right one?

DO: *Make a note of the number of the final choice in the correct part of the answer sheet.*

Demonstrate Problem A5 in the same way as Problem A4.

At any stage between A1 and A5, Problem A1 can be used to illustrate what has to be done, with the request that the child try again.

If the child is unable to solve any of the problems from Problem A1 to A5 correctly, do not continue with the test.

If these five problems are solved, turn to A6.

SAY: Look at the pattern carefully. Now which of these pieces…

DO: *Point to each in turn.*

SAY: ..goes in here?

DO: *Point to the space to be filled.*

SAY: Be careful, only one is right. Which one is it? Be sure you find the right one before you point to it.

DO: *Record the answer finally given.*

Present each problem, giving the same instructions as long as they serve a useful purpose.

If the child is concerned about minor defects in the drawings, assure them that they do not need to worry.

If the child seems to get stuck on a particular item, suggest that they move on and see if they can do the later problems, and then come back to the problem that is causing difficulties.

If, in order to make progress, it seems necessary to do so, ask the person taking the test to guess, "as guesses are sometimes correct".

Record any answer with approval, even if you know it is the wrong answer.

Record answers on the answer sheet, taking care to put them in the right space for that Problem.

Global Processing Speed

Arrow Task

This is a computerised task run on the Macintosh computer. Record the child's first name, ID number and school at the start up screen. The file is called "Arrow Task Script". The program automatically saves the data.

DO: *Start the program and **read the instructions from the screen**. Run through the practice session and make sure the child knows what they have to do, especially what the arrows look like for '"same" and "different" , and which button to push for "same" and "different". If they are unsure, or having trouble, go back and do the practice again.*

Once they are certain of the process and which button is which, you can start the test session. There is little to do, except to oversee the task and make sure the child is not having any difficulties. At the end of the program a thank you message comes onto the screen and shortly after that a picture of a magician's hat as a special message.

Instructions for Practice session (read from screen):

SAY: This is a game where you have to decide whether or not two arrows are pointing the same way, or different ways.

The arrows can point up or down. It doesn't matter which way they are pointing only whether both arrows are pointing the same way or not.

If the arrows are pointing the SAME way, press the GREEN button as fast as you can.
If the arrows are pointing DIFFERENT ways, press the RED button as fast as you can.

It is very important to be as fast as you can without making mistakes.

Now let's practice, press any button to start.

Test Instructions:

SAY: Did you understand what to do?
If not we can practice again.

If you did, we will play some more games.
Press any button to start.

Final Message:

SAY: Thank you for playing this game. You did very well.

Sternberg Memory Scanning Tasks

There are two separate conditions to this task. The first condition is the presentation of word lists on the computer screen, and the second is presentation of random geometric shape lists on the computer screen. They are run on the Macintosh Computer. Record the child's first name, ID number and school. The word task file is called "Word Script"

and the shape task file is called "Sternberg Figures Script". The program records the data automatically.

Word Search

This task is run on the Macintosh computer. The child must first learn/remember four words. After they have learned the words, they will see lists of them varying from 2 – 4 words in length. They have to decide whether the word was present in the list they just saw. The child must press the button box in response to whether the target word was present in the list or not.

DO: *Start the program and read the instructions. The first thing you will have to do is go through the memory trials so that the child remembers the four words.*

Read the instructions from the screen *and ensure that the child repeats the words they have remembered. There will be four memory trials. If the child has not remembered the list after that number of trials, stop the program (Apple and dot keys together) and start again.*

If the child does remember the words, allow the program to continue as the practice trials will begin automatically.

Read the instructions for the practice trials and make sure that the child understands which button is which and what they have to do. If necessary get them to repeat it to you.
Once the child is able to do the task…

SAY: Do you understand how to play this game? (If the answer is yes, continue. If the answer is no, then run through the practice trials again)

When you are ready to start press any button on the box.

Remember to be as fast as you can without making mistakes.

DO: *Supervise the child and watch for any problems. Take them through the practice trials again if they are having difficulties. Start the test session if they have had no problems. At the end a thank you message will appear and a winners trophy picture.*

Memory Trial Instructions (read from screen):

SAY: **I'm going to show you four words one after another. I'd like you to remember the words so that we can use them in a game. Are you ready to remember the words? Press any button to begin.**

Memory Prompt:

SAY: Can you tell me what the four words are?

Press any button to see them again. *This sequence occurs three times, the last prompt is:*

SAY: **Can you tell me what the four words are?**

Practice Instructions:

SAY: Now you will play a game with the words you just learned. Words will come up on the computer screen one after another. There may be two, three or four words one after another.

Once the words are finished a line of stars will appear on the computer screen. After the stars another word will appear. You have to decide if this word was included in the list of words you just saw.

If the word WAS in the list , you press the GREEN button as fast as you can. **If the WAS NOT in the list, you press the RED button as fast as you can.**

Test Instructions:

SAY: Now that you have had a practice, we will play the game some more. **Press any button when you are ready to start.**

Final Message:

SAY: **Thank you very much for playing this game for me. You did very well.**

Figure Search

This task is run on the Macintosh computer. The child will see random lists of geometric shapes from 2 – 4 shapes in length, and then presses the button box in response to whether a target shape was present in the list or not. The process is the same as for the word search.

DO: *Start the program and read the instructions. The first thing you will have to do is go through the memory trials so that the child remembers the four shapes. This will be much more difficult than the word search.* ***The object is that they should not be able to describe the shapes to you. They just have to try and remember what they look like. So don't ask them to tell you what the shapes are.***

Read the instructions from the screen and ask the child if they can remember the shapes. Get them to demonstrate by pointing to the shapes on the page. There will be four memory trials. If the child doesn't think they can remember the shapes after that number of trials, stop the program (Apple and dot keys together) *and start again. They have to be sure that they can remember the shapes before the practice and test trials can begin.*

Memory Trial Instructions (read from screen):

SAY: I'm going to show you four pictures of shapes one after another. I'd like you to remember the shapes so that we can use them in a game.

Are you ready to remember the shapes?
Press any button to begin.

Memory Prompt:

SAY: Can you point to the shapes you saw on this piece of paper?

Let's look at those shapes again. Press any button to continue.

This sequence occurs three times, the last prompt is:

SAY: *Can you show me the four shapes? If the answer is YES, continue, if NO, or incorrect responses, start the memory trial again.*

If the child does remember the shapes, allow the program to continue as the practice trials will begin ***once you press a button on the button box****.*

Read the instructions for the practice trials and make sure that the child understands which button is which and what they have to do. If necessary get them to repeat it to you.

Practice Instructions:

SAY: Now you will play a game with the shapes you just learned. They will come up on the computer screen one after another. There may be two, three or four shapes one after another.

Once the shapes are finished, a line of stars will appear on the computer screen. After the stars, another shape will appear. You have to decide if this shape was in the list of shapes you just saw.

If the shape WAS in the list, you press the GREEN button as fast as you can. If the shape WAS NOT in the list, you press the RED button as fast as you can.

It is important to decide as fast as you can whether the shape was in the list or not without making mistakes.

Once the child is able to do the task…

SAY: Do you understand how to play this game? (If the answer is yes, continue. If the answer is no, then run through the practice trials again)

When you are ready to start press any button on the box.

Remember to be as fast as you can without making mistakes.

DO: *Supervise the child and watch for any problems. Take them through the practice trials again if they are having difficulties. At the end of the program a thank you message will appear on the screen and a first prize ribbon picture.*

Test Instructions:

SAY: *Now that you have had a practice, we will play the game some more. Press any button when you are ready to start.*

Final Message:

SAY: Thank you very much for playing this game. You did very well.

Memory Tasks

Span Tasks with and without Interference

These tasks are run on the Macintosh computer with dual screens. There are two parts to the task. Digit Span and Spatial Span. Both tasks involve three conditions. Record the child's first name, ID number and school. The child's responses are recorded on the keyboard and dual screen by the researcher. The program records the data automatically.

Digit Span Tasks

There are three conditions in this task. The first is simple digit span. The second is digit span with verbal colour interference and the third is digit span with spatial colour interference.

Digit Span

SAY: Now we will play some games on the computer with numbers. In the first game you have to remember some numbers in the order in which they appear one at a time on the computer.

At the end of the numbers you will hear a beep. That is a signal for you to tell me the numbers, **in order,** that you saw on the computer.

If the numbers come up one at a time on the computer like this: "three, nine, five". When you hear a beep, you say to me: "three, nine, five", **making sure the numbers are in the same order that you saw them.**

DO: *Start the task and run the first trial (a practice). Make sure the child understands the task. Keep explaining as you go through the practice, if necessary.*

Record the child's responses in the control window with the keyboard. Press return to log the data and present the next item.

Digit Span with Verbal Interference

SAY: Now we will play another number game on the computer. In this game you have to remember the numbers in the order in which they appear - the same as you did in the first game.

But this time, as well as remembering all the numbers, I want you to tell me what **colour** the number is as you look at it on the computer screen. You will have to do this quickly as another number will appear shortly afterwards.
At the end of the numbers you will hear a beep again. When you hear the beep that is a signal for you to tell me which numbers you saw, **in the order that you saw them**. You don't have to say the colours again.

We'll do a practice and you can see what I mean.

DO: *Start the task and run the practice trial. Make sure the child understands the task. Keep explaining as you go through the practice, if necessary.*

Record the child's responses in the control window with the keyboard. Press return to present the next item.

Digit Span with Spatial Interference

SAY: Now we will play the same game again, but this time instead of saying the colours of the numbers as you see them, you can just point to the colour on the paint palette with the computer mouse *(if the colours are not visible they will be after you press return).*

At the end of the numbers you will hear the same beep as before. When you the beep that is a signal for you to tell me which numbers you saw, **in the order that you saw them**. You don't have to point to the colours again.

We'll do a practice and you can see what I mean.

DO: *Start the task and run the practice session. Make sure the child understands the task. Keep explaining as you go through the practice, if necessary.*

Record the child's responses in the control window with the keyboard. Press return to present the next item.

Spatial Span Tasks

There are three conditions in this task, all run on the Macintosh computer with the dual screen. The tasks are all the same design as the digit span tasks, except instead of digits they use Xs on a grid pattern. The first is spatial span, the second condition is spatial span with verbal colour interference and the third is spatial span with spatial colour interference.

Spatial Span

SAY: Now we will play some games on the computer with Xs on a grid of squares. In the first game you will see an X on the screen in one of these 16 squares (point to grid). The screen will change and another X will appear in a different square. You might see only two Xs in a row, or sometimes more. Your job is to remember which squares the Xs were in, **in the same order as you saw them**.

At the end of the Xs you will hear a beep. When you hear the beep that is a signal for you to click in the squares where the Xs should be **in the order you saw them on the computer**. When you have clicked on all the squares that you can remember, click the **OK** button to start the next lot of Xs to remember.

We'll have a practice so you can see what I mean.

DO: *Start the task and run the practice trial. Make sure the child understands the task. Keep explaining as you go through the practice, if necessary.*

Presentation of the next item is under control of the child, data recording and scoring is automatic.

Spatial Span with Verbal Interference

SAY: Now we will play another game with the Xs on the computer. In this game you have to remember which squares the Xs were in, in the order you saw them - the same as you did in the first game.

But this time, as well as remembering all the numbers, I want you to tell me what **colour** the X is as you look at it on the computer screen. You will have to do this quickly as another X will come shortly afterwards.

At the end of the Xs in the squares, you will hear a beep. When you hear the beep that is a signal for you to click in the squares where the Xs should be **in the order you saw them on the computer**. You don't have to say the colours again. Click the **OK** button when you are ready for some more Xs to remember.

We'll do a practice and you can see what I mean.

DO: *Start the task and run the practice trial. Make sure the child understands the task. Keep explaining as you go through the practice, if necessary.*

Presentation of the next task is under control of the child, data recording and scoring is automatic.

Spatial Span with Spatial Interference

SAY: Now we will play the same game again, but this time instead of saying the colours of the Xs as you see them, you can just point to the colour on the paint palette with the computer mouse.

At the end of the Xs in the squares, you will hear the same beep you have heard before. When hear the beep that is a signal for you to click in the squares where the Xs should be **in the order you saw them on the computer**. You don't have to point to the colours again. Click on the **OK** button when you are ready for some more Xs to remember.

We'll do a practice and you can see what I mean.

DO: *Start the task and run the practice trial. Make sure the child understands the task. Keep explaining as you go through the practice, if necessary.*

Presentation of the next item is under the control of the child, data recording and scoring is automatic.

Nonword Repetition Task

In this task the child hears a series of randomly presented nonwords from the speakers attached to the Macintosh computer. They have to repeat the nonword after they hear it. The children's responses will be recorded for later scoring. The file is called "Nonword Repetition Script".

SAY: Now you will hear some **made-up** words. I want you to say them after you hear them, exactly the same way that the person said them.

I'm going to tape what you say with this little machine.

First we'll have a practice. If I say "bon", I want you to repeat "bon" after me…   ..."bon"….

DO: *Pause and wait for the child to repeat the word. If he or she repeats the word, start the task. If not, go over the instructions again and encourage them to repeat "bon" after you.*

Make sure the child understands that all they have to do is repeat the words exactly as they hear them.

Start the recorder. Say the child's first name, ID number and school into the microphone first, ***then start the program*** *as it starts running the nonwords almost instantly.*

Cognitive Complexity

N-Term Task

This task is a puzzle that children have to solve with rules that they are given on the computer screen. The children have to order coloured blocks according to the rules they are shown. This task is run on the Dell Laptop.

SAY: Now we will play a game on the computer where you have to build towers with coloured blocks from some clues you are given.

DO: *Start the program (double click on N-Term icon). Record the child's first name, ID number and school abbreviation.*

SAY: I'll tell you what to do, so don't worry about reading the words on the screen.

DO: ***Read the instructions from the screen*** *and work through the program with the child. It will stop automatically once they have made five consecutive errors – although they will not know they have made any errors.*

The first part of the program is practice using the mouse. The children have to build towers according to the instructions. Unfortunately you can't bypass this section even for a child with excellent mouse skills. Some children find this section annoying.

After the mouse practice, the practice session starts. There will be a variable number of practice trials depending on how well the child performs. Children who make mistakes will be given extra practice trials automatically.

The instructions on the screen are a variation of this example, and as the presentation of the task is random it is impossible to reproduce exactly the format of any particular instantiation of the task.

SAY: The coloured blocks at the top of the screen are clues to help you work out how to build the tower. See these first two blocks, they are telling us that blue has to be higher than red in the tower. The next two blocks are telling us that green has to be higher than blue in the tower, and the last two blocks are telling us that yellow has to be higher than green in the tower.

When the child has understood the clues, they click OK and they will then be presented with two coloured blocks that they have to move into the tower in the right order.

SAY: *Now you have to work out from the clues where to put the green and red blocks in the tower. Where do you think the green block goes? Now where do you think the red block goes?*

In the practice sessions help the child through this – explain how to use the clues and if they are unsure then tell them how to do it. When they have moved the two blocks they click OK, and a third block will appear on the screen.

SAY: Does the blue block go above, in the middle or below the green and red blocks? (The order this is said in changes randomly throughout the program).

Once the child has completed each problem, they click OK and a new problem appears until the practice session has terminated.

The test session will start automatically, and the instructions will be on the screen and similar to above. There may be more than three clues as more difficult problems appear. In addition, in the more simple problems, the clues are of the colours of adjacent blocks in the tower. The more difficult tower clues involve working out what colours must come in between the coloured blocks they are given. All the information necessary to solve the problem is given in the clues.

When the child has completed the program thank them for playing the game and tell them they did very well.

To stop the program at any point, press SHIFT and ESC together.

Latin Square Task

This task is a puzzle that children have to solve by figuring out which symbol goes into a target square on a grid. The rule is that only one kind of each symbol can appear in any one row or column. So each symbol will appear only once in each row or column. From this information, and clues given in the grid, the target symbol can be determined.

SAY: Now we will play a game on the computer that is a puzzle with lots of squares with some pictures in them. You have to decide which picture goes in the square with the question mark.

DO: *Start the program (double click the Latin Sq Icon). Record the child's first name, ID number and school number .*

DO NOT read the instructions from the screen. Cover the instructions at the top with the cut-down manilla folder. The instruction provided with this program use language that is difficult to understand for children this age.

SAY: I'll tell you what to do, so you don't need to worry about the words on the screen.

SAY: You will see a series of puzzles like this one, with lots of squares in a grid pattern. The grids have rows of squares that go across and columns of squares that go up and down. This is a row, the squares go sideways across the screen (*point to a row*), and this is a column, the squares go up and down the screen (*point to a column*).

DO: Make sure the child understands this concept, get them to point to a row and a column.

SAY: There will be pictures or colours in some of the squares, and one of the squares will have a question mark in it and will be a lighter colour than the other squares.

You have to work out which picture or colour should go in the square with the question mark. The pictures in the other squares of the grid will give you clues.

There is one rule that you have to remember. In each column of squares going up and down, only one of each kind of picture or colour can appear. The same rule applies to each row of squares going across – only one of each kind of picture or colour can be in each row.

I'll show you what I mean on this grid of squares. This grid has four rows of squares and four columns.

Over to the right there are four coloured shapes. A green circle, a red triangle, a blue square and a light blue diamond.

Only one each of the four shapes can be in each row and each column of squares.

If you look at the grid you can see that only one circle, triangle, square and diamond is in each row and column, except for the square with the question mark.

You can work out which shape goes in the square with the question mark by looking at what shapes are in the rows and columns around it.

This column (*point to the one with the question mark*) already has a square, a diamond and a triangle, and this row (*point to the one with the question mark*) already has a diamond, square and triangle as well. Neither the row or the column has a circle, so the circle goes in the square with the question mark.

DO: ***Press the space bar to continue to the practice screen.***

Practice 1

SAY: Now we'll practice a puzzle together.

On the right side are the pictures that can be in this grid of squares. They are a triangle, a circle and a square.

You have to decide which shape goes in the square with the question mark.

Look at the shapes in the other squares to give you some clues about what would go in the square with the question mark.

Can you work out which picture goes in the square with the question mark?

There is only one row, and each picture can be in each row only once. There is already a triangle and a circle in the row, so what do you think should go in the square with the question mark?

When you think you know the answer, click the shape you choose over here with the mouse (*point to the shapes on the right hand side*).

DO: *After the child clicks their choice a "correct" or "incorrect" dialog will appear at the bottom of the screen.*

Read it out and explain to the child why they were right or wrong. If the child was wrong, go over it with them until they understand.

DO: ***Press the space bar for the next practice.***

Practice 2

SAY: Here is another practice puzzle. You can do this one on your own. Remember that only one of each of these pictures (*point to the shapes on the right hand side*) can be in each row and column.

Your job is to find out which picture goes in the square with the question mark using the other shapes in the grid as clues.

When you have decided which picture is the answer, click on it over here (*point to the shapes on the right hand side).*

DO: *After the child clicks their choice a "correct" or "incorrect" dialog will appear at the bottom of the screen.*

Read it out and explain to the child why they were right or wrong. If the child was wrong, go over it with them until they understand.

DO: ***Press the space bar for the next practice.***

Practice 3

SAY: Here is another puzzle. This time there are four pictures that can be in each row and column (point to the shapes on the right hand side). Remember that each picture can only be in each row once, and in each column once.

Your job is to work out which shape should go in the square with the question mark.
When you have decided which shape is the answer, click on it over here (*point to the shapes on the right hand side).*

DO: *After the child clicks their choice a "correct" or "incorrect" dialog will appear at the bottom of the screen.*
Read it out and explain to the child why they were right or wrong. If the child was wrong, go over it with them until they understand.

DO: ***Press the space bar for the next practice.***

Practice 4

SAY: Here is another puzzle. This time there are four pictures that can be in each row and column (point to the shapes on the right hand side).

Remember that each shape can only be in each row once, and in each column once.

Your job is to work out which shape should go in the square with the question mark.

When you have decided which shape is the answer, click on it over here (*point to the shapes on the right hand side).*

DO: *After the child clicks their choice a "correct" or "incorrect" dialog will appear at the bottom of the screen.*

Read it out and explain to the child why they were right or wrong. If the child was wrong, go over it with them until they understand.

Press the space bar.

Test Instructions:

SAY: I'm going to get you to do some more puzzles for me now. Do you have any questions about how to play this game?

DO: Answer any questions the child has, if necessary, stop the program and go back through the practice examples.

SAY: Remember that only **one** of each picture can be in **each row**, and only **one** of each picture can be in **each column**. The pictures might be shapes, or just coloured squares.

If you are sure you understand how to do these puzzles you can start by pressing on the space bar.

This program does not automatically stop when the child makes mistakes. If they don't know the answer and ask you what it is, just tell them to guess. They don't get feedback so will not know they've made mistakes.

Thank them for doing the puzzles and say they did very well.

Auditory Repetition Task

This task is run on the Macintosh computer. It is an auditory task in which the children have to learn to associate the GREEN button on the button box with one sound and the RED button on the button box with another sound. Once this has been achieved, they then have to discriminate between the sounds when presented together.

DO: *The program is contained in the* ***Auditory Temporal Processing Folder*** *and is called* ***Auditory Temporal Processing Script****. Double click the program icon. Start the program by clicking* ***RUN*** *and type in the child's school, id number and first name.*

Read the first instruction screen. Ask the child if he or she is ready to start, then ***PRESS THE SPACEBAR****. You control the flow of the program by pressing the spacebar at instruction screens to move onto each task.*

The program has instructions for you to read out. The first two tasks are associating the buttons with the sounds. The GREEN button is always first and the RED second. You have to make sure that the child is pushing the right button for the right sound in this task.

If the child consistently pushes the GREEN button for the first sound, reward them with a few star stickers after that session. If the child consistently pushes the RED button for the second sound, do the same. This is an operant conditioning process to help them associate the buttons with the sounds.

Detection Instructions (read from screen):

SAY: In a little while you will hear a sound. When you hear the sound I want you to press the GREEN button. Every time you hear the sound, press the GREEN button. I want you to remember the sound that goes with the GREEN button. Are you ready to start?"

When this is completed successfully:

SAY: In a little while you will hear a DIFFERENT sound. When you hear the new sound I want you to press the RED button. I want you to remember that this new sound goes with the RED button. Are you ready to start the sounds?

The third part is a practice discrimination session where they will hear the two sounds together. They have to push the RED button when they hear the first sound they learned and the GREEN button for the second sound they learned. The two sounds appear randomly in four possible combinations. You can help them in this section if they need it, or ask you for help.

Discrimination:

SAY: Now that you have learned the sounds I will play some more. Remember to press the GREEN button for the first sound you learned, and the RED button for the second sound you learned.

Listen carefully. This time there will be two sounds together. The sounds are the same ones you have just learned. There may be two of the same sound in a row, or one of each.

We will practice first. Are you ready to practice?

The fourth part is another sequencing session where they have to do exactly what they did in the practice, but without your help.

Sequencing:

SAY: Now that you've had a practice, I'd like you to try some more. Remember to press the GREEN button for the first sound you learned and the RED button for the second sound you learned. This time I won't help you.

Listen carefully. You will hear two sounds together. There may be two of the same sound, or one of each sound. Are you ready to start?

The fifth and final part is the same task with different intervals between the tones. The sounds are sometimes very close together and sometimes there is a long interval between them. This part takes a bit longer than the first four.

Rate Processing Instructions:

SAY: Now we will do that again. This time the two sounds may be closer together so listen very carefully.

Remember to press the GREEN button for the first sound you learned and the RED button for the second sound you learned.

Are you ready to start?

To stop the program at any stage press APPLE and DOT together.

The whole program takes about 10 minutes. At the end a thank you message will appear, and then a picture of a star.

Final Message:

SAY: Thank you very much for playing this game. You did very well.

Appendix C
Language and Physical Risk Index Items, Parental Interview Proforma, and Data Entry Code Book

This Appendix contains a copy of the form used in the structured telephone interview administered to the parents of participating children. It also contains the code book used for this data. Two tables are also included, these contain the constituent items of the language and physical risk indices.

Table 17

The Interview Items Used to Create the Language Risk Index

Interview Items
The age at which the child started babbling
The age at which the child spoke his or her first word
The age at which the child spoke two and three word utterances
The age at which the child spoke fluently
Estimation of how many books are in the house
Was the child read to when little?
Is the child still read to, or does the child read to the parents?
Has the child ever been diagnosed with a speech, language or learning problem?
Has any other blood relative been diagnosed with a speech, language or learning problem?
Has the child had problems with spelling?
Has the child had problems with reading?
Has the child had problems writing?
Has the child been kept down at school?
Has the child needed special tutoring at school or elsewhere?
The number of episodes of Otitis Media the child has had

Table 18

The Interview Items Used to Create the Physical Risk Index

Interview Items
Did the mother take any drugs / medication when pregnant?
How many cigarettes did the mother smoke per day when pregnant?
How many standard drinks of alcohol did the mother drink per week when pregnant?
How premature was the child, if at all?
What was the child's birth weight?
Were there any significant problems at birth?
Were there any significant health problems in the child's first year?
What age was the child when he or she first responded to the major caregiver?
What age was the child when he or she first rolled over?
What age was the child when he or she started to crawl?
What age was the child when he or she first sat up?
What age was the child when he or she first walked?
Has the child ever had any vision problems?
Has the child ever had any hearing problems?
Has the child ever had any coordination problems?
Has the child ever had any concentration problems?
Has the child ever had any memory problems?
Has the child ever suffered any head injuries?
Has the child ever lost consciousness?
Has the child ever been diagnosed with Attention Deficit Hyperactivity Disorder?
Has the child ever been diagnosed with Conduct Disorder?

DEVELOPMENTAL INTERVIEW

Date: __________ School: ____

FAMILY INFORMATION

Child's Name:____

Birthdate: ___________________________ Age: __________ Sex: MaleFemale

Home Address: ___________________________Phone: ____________________

____

Record details of the parent/guardian participant only

Mother's Name: _______________________________ Age: _________________

Years of Education: _____________ Occupation: ___________________________

Father's Name: ________________________________ Age: _________________

Years of Education: _____________ Occupation: ___________________________

Guardian's Name: ______________________________ Age: _________________

Relationship to child: ____

Years of Education: _____________ Occupation: ____________________________

LANGUAGE HISTORY

Primary language spoken at home: _______________________________________

Other languages spoken at home: ____

Approximately how many books would you have in your home? _________________

How often would you buy a newspaper or magazine?

Never Rarely Monthly Weekly Daily

Do you subscribe to any? Yes No If yes, which? ____________________

Are you or anyone in the family a member of a library? Yes No

If yes, how often would you/they go to the library?

Rarely Monthly F/Nightly Weekly

Do you read to your child, or have them read to you? Yes No

If yes, how often? Rarely Monthly Weekly Daily
Did you or anyone in your family read to your child when they were little? Yes No

If yes, approximately how often? Rarely Monthly Weekly Daily

Has your child ever been diagnosed with a speech, language or learning problem?

Yes No

If yes, what kind of problem: ____

When was it diagnosed? ____

What kind of treatment, if any:
____

Have other family members been diagnosed with a speech, language or learning problem? Yes No If yes, which family member/s:
____

What was the diagnosis:____

EDUCATIONAL HISTORY

Does your child, or has your child ever in the past, had problems with:

______ Reading ______ Spelling ______ Writing _______ Maths

Has your child ever been kept down a grade? Yes No

If yes, what was the reason:
____

Has your child ever received special tutoring or therapy at school? Yes No

If yes, please describe:
____

DEVELOPMENTAL HISTORY

Was your child premature? Yes No If yes, by how many weeks: _________

What was the child's birth weight? ____

Were there any defects or complications? Yes No

If yes, what? ____

Were there any special problems in the growth and development of your child during the first few years? Yes No

If yes, describe:

____

____

What age did your child first:	*Age & Details*
Show a response to mother/caregiver	___________________
Roll over	___________________
Sit alone	___________________
Crawl	___________________
Walk alone	___________________
Babble	___________________
Speak his or her first word	___________________
Put several words together	___________________
Speak fluently	___________________

MEDICAL HISTORY

Has your child ever had any of these medical problems, and approximately how old were they at the time?

		Age & Details
Hearing or ear problems Including OM infections, gromits etc	_________	___________________
Vision or eye problems	_________	___________________
Coordination problems	_________	___________________
Measles	_________	___________________
Meningitis	_________	___________________
Encephalitis	_________	___________________
Convulsions	_________	___________________
Head Injuries	_________	___________________

Loss of consciousness	_________	__________________
Frequent or severe headaches	_________	__________________
Difficulty concentrating	_________	__________________
Memory problems	_________	__________________
Epilepsy	_________	__________________
Attention deficit disorder with/without hyperactivity	_________	__________________
Conduct disorder	_________	__________________
Congenital disorders such as Down's Syndrome, Cystic Fibrosis, Cerebral Palsy or other	_________	__________________
Intellectual disability	_________	__________________

Any other illness
or disorder – *note details*____

____

During pregnancy did mother:

Take medication? Yes No If yes, what kind?
____

Smoke? Yes No If yes, how many per day? ____________________________

Drink alcohol? Yes No If yes, how many standard drinks per week?_________

Adapted from: Sattler, J. M. (1992). Assessment of children (3rd ed). San Diego: Jerome M Sattler Publisher, Inc.

Code Book for the Developmental Interview

#	Name	Description	Type	Input
1	ID	Child's ID number	NUM	Numerical
2	School	School Name	NUM	
3	Age	Child's Age	NUM	Age in Months
4	Sex	Child's Sex	NUM	1 = Female 2 = Male
5	Adult	The adult participant	NUM	1 = Mother 2 = Father 3 = Guardian
6	Adultage	The adult's age	NUM	
7	Edyears	The adult's years education	NUM	
8	Occupat	The adult's occupation	NUM	5 = Professional 4 = Semi-Professional, Managerial, Technical 3 = Skilled, Clerical, Home Duties 2 = Unskilled Labour 1 = Unemployed
9	Prilang	Primary language spoken at home	STRING	
10	Othlang	Other languages spoken at home	STRING	
11	Books	Number of books in the home	NUM	5 = None 4 = 1 – 20 3 = 21 – 50 2 = 51 – 99 1 = >100
12	Newsmags	How often they buy a newspaper or magazine	NUM	5 = Never 4 = rarely 3 = monthly 2 = weekly 1 = daily
13	Library	Member of library	NUM	5 = Not member 4 = rarely 3 = monthly 2 = fortnightly 1 = weekly
14	Readchil	Read to child, or child read to them	NUM	5 = Never read 4 = rarely 3 = monthly 2 = weekly 1 = daily
15	Readlitt	Was the child read to when little	NUM	5 = Never 4 = rarely 3 = monthly 2 = weekly 1 = daily
16	Langdiag	Ever diagnosed with language speech or learning problem	NUM	5 = yes 1 = no

17	Diagnos	If yes, what diagnosis	STRING	Words
18	Whendiag	When was the child diagnosed	STRING	
19	Treatmet	What kind of treatment	STRING	
20	Otherdia	Any other family members diagnosed	NUM	5 = yes 1 = no
21	Others	Which others	STRING	
22	Diagoth	What was their diagnosis	STRING	
23	Probread	Does the child have/had reading problems	NUM	5 = yes 1 = no
24	Probspel	Spelling problems	NUM	5 = yes 1 = no
25	Probwrit	Writing problems	NUM	5 = yes 1 = no
26	Probmath	Maths problems	NUM	5 = yes 1 = no
27	Keptdown	Has the child ever been kept down	NUM	5 = yes 1 = no
28	Reasdown	For what reason	STRING	
29	Spectut	Has the child received special tutoring	NUM	5 = yes 1 = no
30	Tuttype	What type	STRING	
31	Premmy	Was the child premature and by how many weeks	NUM	4 = > 8 weeks 3 = 5 – 8 weeks 2 = 1 – 4 weeks 1 = not premature
32	Birthwei	Child's birth weight	NUM	4 = less than 4lbs 3 = 4 – 5.5lbs 2 = 5.5 – 7lbs 1 = > 7lbs
33	Birtprob	Any birth defects or complications	NUM	4 = yes 1 = no
34	Defcompl	What defects or complications	STRING	
35	Probfirs	Any special probs in the first year	NUM	4 = yes 1 = no
36	Whatprob	What problems	STRING	
37	Ageresp	What age did child first show a response to mother/caregiver		4 = >3 mths 1 = 4wks – 3 mths
38	Ageroll	Roll over		4 = >7mths 1 = 3wks – 7mths
39	Agesit	Sit alone		4 = >9mths 1 = 5 – 9 mths
40	Agecrawl	Crawl		4 = >11mths 1 = 5 – 11 mths
41	Agewalk	Walk alone		4 = >17mths 1= 9 – 17mths
42	Agebabb	Babble		5 = >10 mths 1 = 6 – 10 mths
43	Ageword	Say first word		5 = >15 mths 1 = 10 – 15 mths

44	Agewords	Combine several words		5 = >20 mths 1 = 12 – 20 mths
45	Agefluen	Speak fluently		5 = >3 yrs 1 = 2 – 3 yrs
46	Earprobs	Has the child ever had ear problems	NUM	4 = yes 1 = no
47	Earcode	Code for severity of OME incidence (from information gained in item 46)	NUM	5 = Constant OMEs and / or hearing loss, gromits 4 = 6 – 8 OME incidents, gromits 3 = 3 – 5 OME incidents 2 = Infrequent (1 – 2 OMEs) 1 = none or Tropical Ear, unidentified earaches
48	Visprobs	Vision/eye probs	NUM	4 = yes 1 = no
49	Coorprob	Coordination problems	NUM	4 = yes 1 = no
50	Measles	Measles	NUM	4 = yes 1 = no
51	Meningit	Meningitis	NUM	4 = yes 1 = no
52	Enceph	Encephalitis	NUM	4 = yes 1 = no
53	Convuls	Convulsions	NUM	4 = yes 1 = no
54	Headinj	Head injuries	NUM	4 = yes 1 = no
55	Losscons	Loss of consciousness	NUM	4 = yes 1 = no
56	Headach	Headaches	NUM	4 = yes 1 = no
57	Concent	Difficulty concentrating	NUM	4 = yes 1 = no
58	Memory	Memory problems	NUM	4 = yes 1 = no
59	Epilepsy	Epilepsy	NUM	4 = yes 1 = no
60	Addadhd	ADD/ADHD	NUM	4 = yes 1 = no
61	Conduct	Conduct disorder	NUM	4 = yes 1 = no
62	Congenit	Congenital disorders	NUM	4 = yes 1 = no
63	Intellec	Intellectual disorders	NUM	4 = yes 1 = no
64	Otherill	Other illnesses/disorders	NUM	4 = yes 1 = no
66	Pregmed	Did mother take medication during pregnancy	NUM	4 = yes 1 = no

67	Smokamt	How much mother smoked in cigs per day	NUM	4 = >= 14 3 = 8 – 13 2 = 1 – 7 1 = none
68	Alcamt	How much mother drank in standard drinks per week	NUM	4 = >= 14 3 = 8 – 13 2 = 1 – 7 1 = none

Several items are to obtain information for exclusionary purposes. For example, whether English is the child's first language and any diagnoses they may have had, including intellectual disability. There are items not coded here which were information if items were answered in the affirmative.

Indices - Proposed items for the Language and Physical Risk indices include:

Language Developmental Risk Index Items

11 - 16, 20, 23, 24, 25, 27, 29, 42, 43, 44, 45, 47.

Physical Developmental Risk Index Items

31, 32, 33, 35, 37, 38, 39, 40, 41, 45, 46, 48 – 68.

Appendix D

Additional Data and Analysis Information

This Appendix contains tables of means and standard deviations for the language ability groups for the tests/tasks/measures. It also contains the covariance matrix of all the observed variables entered into the structural equation models.

Table 19

Mean Index Scores and Standard Deviations for Low, Average and High Language Ability Groups for the Language and Physical Risk Indices

	Low Language Ability Group		**Average Language Ability Group**		**High Language Ability Group**	
	Mean	**SD**	Mean	**SD**	Mean	**SD**
Language Risk Index	39.30	*8.91*	23.70	*7.53*	18.60	*4.65*
Physical Risk Index	32.50	*11.19*	23.70	*7.45*	27.10	*7.45*

Table 20

Means and Standard Deviations of Reaction Time Scores for Low, Average and High Language Ability Groups for Processing Speed Tasks

Task	Low Language Ability Group		Average Language Ability Group		High Language Ability Group	
	M	*SD*	*M*	*SD*	*M*	*SD*
RAN (s)	97.65	*25.62*	87.76	*24.89*	82.45	*13.56*
Arrow (ms)						
Same	1054	*43*	910	*39*	977	*64*
Different	1099	*49*	1018	*51*	962	*63*
Word (ms)						
'Yes' Probe	2029	*480*	1548	*635*	1486	*423*
'No' Probe	1872	*582*	1358	*457*	1251	*289*
Figure (ms)						
'Yes' Probe	2577	*1141*	1832	*598*	1853	*445*
'No' Probe	2368	*1100*	1839	*640*	1564	*443*

Table 21

Mean Number Correctly Discriminated and Standard Deviations for Low, Average and High Language Ability Groups for the Auditory Repetition Task

	Low Language Ability Group		Average Language Ability Group		High Language Ability Group	
	M	*SD*	*M*	*SD*	*M*	***SD***
Interstimulus Interval in ms						
10	10.00	*2.04*	10.10	*1.20*	9.22	*1.46*
30	8.88	*1.06*	10.30	*3.56*	11.00	*1.34*
60	8.88	*2.19*	8.50	*3.92*	10.94	*2.08*
120	8.58	*2.69*	9.30	*2.54*	12.87	*2.03*
180	8.71	*2.12*	9.10	*4.04*	11.84	*2.05*
240	9.01	*2.41*	10.20	*3.52*	12.36	*1.98*
300	10.15	*2.15*	9.90	*3.96*	12.61	*1.87*
360	9.78	*2.71*	9.60	*3.78*	13.10	*2.62*
420	11.37	*3.13*	12.20	*3.94*	14.57	*1.31*

Table 22

Mean Number Correct and Standard Deviations of Scores for Low, Average and High Language Ability Groups for the Cognitive Capacity Tasks

Task	Low Language Ability Group		Average Language Ability Group		High Language Ability Group	
	M	*SD*	*M*	*SD*	*M*	*SD*
NRT						
1 Syllable	13.80	*.79*	13.50	*1.08*	13.90	*1.10*
2 Syllables	34.70	*1.70*	34.00	*1.15*	35.80	*.92*
3 Syllables	32.60	*1.58*	33.30	*1.16*	33.20	*1.03*
4 Syllables	39.10	*5.47*	45.80	*6.81*	49.60	*2.50*
Memory Task						
Digit/None	5.10	*2.38*	6.00	*1.56*	6.00	*1.05*
Digit/Verbal	2.50	*1.18*	2.30	*.48*	3.30	*1.16*
Digit/Spatial	2.70	*1.16*	3.30	*3.37*	4.30	*1.34*
Spatial/None	2.50	*1.27*	4.30	*1.57*	5.30	*1.64*
Spatial/Verbal	2.70	*1.42*	3.70	*1.89*	5.00	*2.00*
Spatial/Spatial	.30	*.48*	.60	*.84*	.70	*.82*
N-Term Task						
Binary	5.60	*2.50*	6.67	*1.00*	7.55	*.60*
Ternary	4.41	*1.17*	5.18	*1.79*	6.28	*1.57*
Latin Square Task						
Binary	6.30	*2.87*	7.12	*2.61*	8.65	*2.00*
Ternary	4.40	*2.41*	6.30	*2.87*	8.02	*1.63*
Quarternary	1.70	*1.42*	2.40	*1.58*	3.62	*1.83*

Table 23
Covariance Matrix for all Observed Variables used in the Structural Equation Models

N=158	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Sentence Structure	9.557														
2. Concepts & Directions	3.446	8.473													
3. Word Classes	3.568	4.207	7.959												
4. Word Structure	3.316	3.562	4.377	6.359											
5. Formulated Sentences	4.497	4.589	5.131	4.284	7.823										
6. Recalling Sentences	3.752	5.809	4.778	4.412	5.878	8.694									
7. SPM Set A	0.800	0.783	1.058	0.771	0.942	0.636	1.562								
8. SPM Set B	2.703	2.834	2.919	2.420	2.573	2.377	1.420	5.949							
9. SPM Set C	1.985	1.453	1.863	1.792	1.422	0.789	0.938	3.075	5.308						
10. SPM Set D	3.276	2.142	3.021	2.459	2.625	1.659	1.071	4.370	4.225	8.559					
11. SPM Set E	1.046	0.621	0.939	0.668	0.711	0.484	0.368	1.221	1.053	1.730	1.573				
12. ATP ISI 120	1.266	1.655	1.937	1.192	2.060	1.995	0.525	1.216	0.600	1.602	0.288	6.809			
13. ATP ISI 180	0.823	1.692	1.354	0.671	1.090	1.135	0.573	1.440	1.001	1.347	0.116	4.019	8.687		
14. ATP ISI 240	1.065	1.661	1.738	0.858	1.221	1.408	0.603	1.512	0.141	0.852	0.528	4.609	5.363	8.948	
15. ATP ISI 300	1.274	2.136	2.039	1.017	2.026	1.370	0.581	1.569	0.982	1.582	0.500	4.881	5.734	5.959	9.119
16. ATP ISI 360	2.233	2.665	2.047	0.802	2.167	2.026	1.166	2.412	1.604	2.555	0.567	5.160	6.200	6.912	6.980
17. Non-word Repetition	5.851	7.843	8.427	7.851	8.094	10.527	1.976	4.247	3.309	5.016	1.827	3.808	3.663	3.243	5.447
18. Digit Span	0.930	1.108	1.702	1.585	1.358	1.226	0.162	0.726	0.984	1.464	0.339	0.668	0.530	0.604	0.578
19. Spatial Span	1.069	1.542	0.781	0.953	1.194	1.166	0.301	1.156	0.550	1.121	0.376	0.783	0.690	0.612	0.663
20. N-Term Task	1.359	1.233	1.698	1.179	1.553	1.491	0.826	2.340	1.006	2.644	0.248	1.909	0.950	0.271	0.962
21. Latin Square Task	3.897	3.861	4.324	2.303	4.177	3.389	1.690	3.232	2.789	5.315	1.366	2.147	2.548	3.147	1.860
22. RAN	-0.477	-0.890	-0.324	-0.572	-0.505	-.0848	-0.204	-0.744	-0.358	-0.408	-0.112	-0.447	-0.753	-0.695	-0.715
23. Arrow Task	-0.421	-1.016	-0.968	-0.208	-1.015	-1.146	-0.477	-0.876	-0.719	-0.864	-0.403	-0.109	-0.360	-0.133	-0.063
24. Word Task	-3.322	-7.997	-5.105	-3.305	-5.034	-7.129	-1.204	-3.884	-2.489	-3.531	-1.754	-1.855	-2.592	-1.963	-2.889
25. Figure Task	-1.415	-5.484	-4.861	-3.446	-4.894	-6.085	-1.969	-3.477	-1.723	-2.163	-1.719	-2.426	-3.586	-5.640	-3.447
26. Language Risk Index	-1.006	-1.250	-1.271	-1.062	-1.257	-1.416	-0.124	-0.418	-0.343	-0.642	-0.236	-0.403	-0.219	-0.261	-0.606
27. Physical Risk Index	-0.439	-0.556	-0.748	-0.658	-0.630	-0.508	-0.181	-0.322	-0.230	-0.474	-0.063	-0.038	-0.341	-0.073	-0.294
28. Parent Age	1.396	1.639	1.432	1.433	2.644	2.129	0.627	2.653	1.327	1.301	0.749	1.751	4.032	4.325	4.280
29. Parent Years Education	1.017	1.540	1.574	2.068	1.745	1.749	0.506	1.229	0.436	0.675	0.131	0.455	0.814	0.227	0.192
30. Parent Occupation	0.577	0.779	0.796	0.970	0.922	0.803	0.245	0.602	0.230	0.233	0.045	0.335	0.561	0.523	0.538

Table 23 continued.

Covariance Matrix for all Observed Variables used in the Structural Equation Models

N=158	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
16. ATP ISI 360	12.651														
17. Non-word Repetition	5.529	48.649													
18. Digit Span	1.036	2.919	2.580												
19. Spatial Span	0.668	1.946	0.503	3.629											
20. N-Term Task	1.615	4.490	0.155	1.287	7.894										
21. Latin Square Task	4.522	5.984	1.071	1.367	4.018	20.825									
22. RAN	-1.178	-1.714	-0.311	-0.317	-0.396	-0.896	1.010								
23. Arrow Task	-0.345	-2.691	-0.510	-0.920	-0.499	-1.819	0.743	5.650							
24. Word Task	-2.889	-13.447	-2.064	-2.951	-1.002	-8.929	2.447	6.357	45.342						
25. Figure Task	-2.813	-15.315	-2.585	-2.677	-0.173	-5.5415	1.576	7.908	35.219	57.598					
26. Language Risk Index	-0.444	-2.620	-0.388	-0.402	-0.237	-1.131	0.276	0.327	2.037	2.028	0.979				
27. Physical Risk Index	-0.246	-1.164	-0.190	-0.167	-0.254	-0.775	0.133	0.074	0.688	1.306	0.368	0.947			
28. Parent Age	4.773	2.545	0.310	1.346	0.753	1.052	-0.795	-1.027	-5.986	-5.709	-0.220	-0.232	28.437		
29. Parent Years Education	1.048	2.755	0.658	0.829	0.628	0.246	-0.064	-0.242	-0.915	-2.729	-0.420	-0.416	3.460	6.623	
30. Parent Occupation	0.740	1.527	0.247	0.323	0.308	0.681	-0.097	-0.159	-1.090	-1.462	-0.237	-0.185	1.633	1.434	0.787

Note. Abbreviations are: SPM = Standard Progressive Matrics, ATP = Auditory Temporal Processing, ISI = Interstimulus Interval, RAN = Rapid Automatized Naming. Parent age was originally included in the model, but removed due to lack of reliability.

Table 24

Correlation Matrix for the Latent Variables in the Structural Equation Models

Latent Variable	1	2	3	4	5	6	7
1. L/ABIL	-						
2. NVIQ	.526	-					
3. VWM	.926	.567	-				
4. CAP	.627	.757	.749	-			
5. GPS	-.410	-.318	-.580	-.420	-		
6. ATP	.301	.244	.430	.322	-.249	-	
7. D/RISK	-.654	-.314	-.664	-.415	.388	-.286	-
8. SES	.464	.241	.451	.318	-.262	.194	-.330

Note. Abbreviations are: L/ABIL = Language Ability, NVIQ = Nonverbal IQ, VWM = Verbal Working Memory, CAP = Nonverbal Cognitive Capacity, GPS = Global Processing Speed, ATP = Auditory Temporal Processing, D/RISK = Developmental Risk, SES = Socioeconomic Status.