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Children's Language Ability

A Multi-Theoretical Approach

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Chapter 1

From Language Disability to Language Ability

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 this book, is research on the characteristics of children who do not acquire language at the same rate or with the same proficiency as other children. The research on language *disability* has provided much of what we know about language *ability*.

Within the area of language disability 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 this book. 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.

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 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.

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 largely been ignored in language disorder research (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).

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 book focuses 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.

Temporal Processing

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 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, Delancy & 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, 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.

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.

Working Memory/Cognitive Capacity

There have been 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.

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.

Other 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, 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.

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 'word-like' 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 word-likeness than they were in repeating nonwords rated as high in word-likeness, indicating that linguistic information aided their repetition of the nonwords high in word-likeness.

Even though it is acknowledged within the literature that the nonword repetition task is affected by how word-like 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 word-likeness.

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 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 book, 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 polysyllabic 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.

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 earlier 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.

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, 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.

Summary

This chapter 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.

The remainder of the book addresses these issues by presenting a research project investigating the relationships between language ability, nonverbal intelligence, working memory, processing speed, temporal processing and social, environmental and developmental influences. Chapter 2 presents the rationale, design and methodology of the research. Chapters 3, 4 and 5 present the results of the research and Chapter 6 discusses the results and the implications for children's language ability research and for practitioners working with children.