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SPEECH PRODUCTION IN ADOLESCENTS WITH SPECIFIC LANGUAGE IMPAIRMENT

Jeán Henrica Bowker

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ABSTRACT

There has been limited investigation into the nature of specific language impairment (SLI) in adolescence, and even less investigation into speech production in SLI, particularly beyond the preschool years. Phonological output is crucial to oral expressive language, one of the characteristic areas of deficit in SLI. It was hypothesized that adolescents with SLI present with residual speech errors. Accordingly, this study investigated the presence, nature and cause of speech deficits in adolescents with persistent SLI.

Adolescents aged 13.0-14.0 years with persistent SLI (n=31) were compared to typically developing (TD) peers (n=31) on an Oral Motor Evaluation (OME) and a Speech Assessment Battery (SAB), consisting of: Multisyllabic Word Repetition, Nonsense Word Repetition, Phrase Repetition, Sentence Repetition and Tongue Twisters. Tasks were analysed in terms of accuracy and the amount of effort required, to determine efficiency and automaticity of phonological output. All participants completed a battery of memory tasks and the language abilities of the SLI group were evaluated. Caregivers completed questionnaires investigating risk factors.

Results indicated that adolescents with persistent SLI produced a higher number of inconsistent and context-dependent deviant speech behaviours than TD peers, involving syllable structure changes (phoneme additions/omissions), phoneme substitutions, fluency errors and repetitions/revisions. Participants with SLI also had a higher incidence of neuromotor deficits. Persistent SLI appears to relate to a multifactorial etiology, involving both genetic and early history factors. There was high comorbidity of attention deficits, with implications for resource allocation.

Results were interpreted within a functional capacity viewpoint. Speech deficits are thought to contribute to a threshold effect, where even subtle deficits in one area can compromise processing in another area. Speech production in this population appears to be more resource-demanding than in TD peers, which may affect concurrent performance on linguistic and memory tasks. This hypothesis is supported by the high correlation between speech tasks and expressive syntax for SLI participants. The high incidence of speech deficits in adolescents with SLI

has implications for research and clinical practice with individuals of all ages with SLI.

Keywords: Persistent specific language impairment (SLI), speech production, motor coordination and planning, auditory memory, resource allocation.

Declaration

I declare that this thesis is my own unaided work. It is submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other university.

_____

Jeán Bowker

16th day of July, 2007.

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LIST OF ABBREVIATIONS

AD(H)D	Attention Deficit (Hyperactivity) Disorder
AMBIG	Understanding Ambiguous Sentences (TOLC)
CAS	Cognitive Assessment System
CELF-R	Clinical Evaluation of Language Fundamentals-Revised
fMRI	Functional Magnetic Resonance Imaging
FS	Formulated Sentences (CELF-R)
GDE	Gauteng Department of Education
LG	Listening Grammar (TOAL-2)
LH ratio	Likelihood Ratio
LSEN	Learners with Special Educational Needs
LV	Listening Vocabulary (TOAL-2)
MLU	Mean Length of Utterance
MND	Minor Neurological Dysfunction
MWL	Multisyllabic Word List
NWR	Nonsense Word Repetition
OM-E	Otitis Media with Effusion
OME	Oral Motor Evaluation
PASS	Planning, Attention, Simultaneous and Successive Processing
PhAB	Phonological Assessment Battery
PR	Phrase Repetition
SAB	Speech Assessment Battery
SD	Standard Deviation
SD	Speech Delay
SD-AOS	Speech Delay-Apraxia of Speech
SD-DYS	Speech Delay-Dysarthria
SD-GEN	Speech Delay-Genetic
SD-OME	Speech Delay-Otitis Media with Effusion
SDCS	Speech Disorders Classification System
SLI	Specific Language Impairment
SLP	Speech-Language Pathologist
SR	Sentence Repetition
TD	Typically Developing
TOAL-2	Test of Adolescent Language-Revised
TOLC	Test of Language Competence
TT	Tongue Twisters
WA	Word Associations (CELF-R)

1 Introduction

The area of specific language impairment (SLI) has been widely researched and is a popular topic in research journals. The primary focus, however, has been on preschool and early school aged children. Adolescents with SLI have received little research attention. Similarly, phonological output has been the stepchild of SLI research – seldom acknowledged, often ignored and frequently excluded. Nonetheless, the study of speech difficulties is the only truly unique characteristic of a speech-language pathologist's (SLP's) training and job (Pascoe, Stackhouse & Wells, 2006), and it is this researcher's belief that we are undermining our professional identity by reducing our focus on speech output. Furthermore, community identification of SLI is still strongly influenced by expressive skills, particularly phonological skills (Tomblin, Records, et al, 1997). From a clinical perspective, it is therefore important to extend our knowledge regarding the manifestation of speech disorders in individuals with SLI. Accordingly, this study investigated the presence and nature of speech deficits in adolescents with SLI. As Pascoe et al (2006) suggested, this study is about "putting the speech back into speech-language therapy".

The impetus for this study came largely from the researcher's clinical experience with adolescents with SLI. Clinicians are faced with clients who do not fit neatly into diagnostic categories, and often have to deal with overlapping or comorbid disorders. In clinical practice it is apparent that many adolescents with SLI do not have good speech production abilities, yet this area has been poorly researched and there is little empirical data to guide the clinician's intervention with such clients. While purely theoretical research is useful to increase our understanding of theoretical phenomena, ultimately in a clinically oriented field such as Speech-Language Pathology, research should guide practice, and practice should guide research (Pascoe, Stackhouse & Wells, 2006). It is therefore important not to study disorders such as SLI in isolation, but to look at overlap and interaction effects among communication disorders. This

study therefore aimed to investigate the presence and nature of speech deficits in adolescents with SLI.

Apart from the clinical implications, the presence of speech deficits in adolescents with SLI also has implications for theory. The impact of potential speech deficits in older individuals with SLI has largely been ignored. Studies on preschoolers with SLI have sometimes considered speech output factors in designing studies involving verbal output tasks. In contrast, studies with older children appear to take the perspective that speech deficits have been resolved, and that if there are no overt, consistent speech errors evident in participants with SLI, speech output factors would not impact on the results of the study. However, there is evidence that individuals with a history of speech deficits still have residual errors in adolescence and adulthood (e.g. Lewis & Freebairn, 1992) and children with reading deficits may have inconsistent, context-dependent speech errors (Kamhi & Catts, 1986; Kamhi, Catts, Mauer, Apel & Gentry, 1988). Since there is substantial comorbidity of speech and language disorders, it is likely that many adolescents with SLI may have a history of speech impairment, and thus may still have residual errors. Similarly, many children with SLI later develop reading disorders, and may thus have inconsistent speech errors which could impact on verbal output tasks, such as nonword repetition which is often used in research in the area of SLI. However, the presence of speech deficits has not been confirmed specifically in an adolescent population with SLI, thus highlighting the need for a study in this area.

This study will show that speech production and neuromotor deficits are common in adolescents with SLI. The speech production deficits are context-dependent in that they are most evident in tasks which are motorically and phonologically complex. Compared to typically developing (TD) peers, speech production in adolescents with SLI thus appears to be less automatic and more resource-demanding. This study will further demonstrate that there are interactions among performance on speech tasks and performance on language and memory tasks.

One could argue that if speech errors are not overt or consistent, a study in this area would not yield findings of any real consequence to the field of SLI. However,

this study proposes that speech production abilities contribute to the functional capacity of the language processing system, particularly with regard to oral expressive language, which is often regarded as one of the characteristic deficit areas in SLI. Furthermore, this study proposes that a threshold effect exists. The threshold effect implies that a subtle deficit in an area such as speech production may not be of significance when seen in isolation. However, when coupled with linguistic and memory deficits (albeit subtle deficits), a cumulative effect arises, which may then manifest as the deficits regarded as characteristic of SLI. This study therefore argues that for some individuals the characteristic linguistic and memory deficits described in SLI are exacerbated, in part, by poor speech production abilities.

In the sections below, the primary concepts relevant to this study, namely speech, SLI and adolescence will be further elucidated.

1.1 Speech and Speech Disorders

The study of language impairment would not be complete without including speech, as speech is the externalized expression of language (van der Merwe, 1997), involving both a linguistic component (phonological knowledge) and a neuromotor component (articulation). Speech is fundamental to verbal communication and speech output is an essential component of the language processing chain. There is thus good reason to investigate speech production in individuals with SLI.

Language and speech disorders often co-occur, yet these two disorders have usually been studied in isolation. The comorbidity of SLI and speech disorders has been reported in a number of studies (see Chapter 2). However, these studies investigated young children with SLI, and comorbidity has not been investigated in adolescents. There is evidence that school-aged children with reading disorders often have speech deficits, and it is possible that some of these children present with SLI. There is also evidence that for many children with a preschool history of speech disorders, these disorders persist in a subtle form into adolescence and adulthood. It would therefore appear likely that at least some adolescents with persistent SLI may present with speech deficits.

Speech deficits exist on a continuum (Crary, 1993) and may take the form of a mild disorder, consisting of inconsistent, context-dependent factors. Speech errors in non-impaired populations may be influenced by a variety of factors, including linguistic demands. In adolescents with SLI, whose linguistic deficits (particularly poor vocabulary, morphosyntax, phonological memory and phonological representation) may impact on some of these factors, the likelihood of speech errors is probably increased.

It is widely accepted that the term SLI may be a misnomer, as children with this disorder do not have deficits only in the area of language. As is discussed in Chapter 3, it is increasingly recognized that these children may have perceptual, cognitive and motor limitations. It is the hypothesis of this study that many adolescents with SLI present with subtle motor deficits, which could also impact on their speech production, hence resulting in mild speech deficits.

Models of speech production have generally focused either on sensorimotor processes or linguistic or lexicalization processes (see Chapter 2) to describe how thoughts are transformed into audible speech output. Many children with SLI have motoric deficits (Hill, 2001) and it is therefore hypothesized that they may struggle with the motoric aspects of speech production. At the same time, their linguistic deficits may impact on lexicalization, which relies on good phonological representation and vocabulary knowledge, both of which have been shown to be compromised in some children with SLI.

Research into speech production has demonstrated that speech production factors interact with language factors. For example, as language demands increase, fluency tends to decrease (Kleinow & Smith, 2000; Tetnowski, 1998). In individuals with language deficits such as SLI, language demands may frequently exceed capacity, which may impact on aspects of speech production. There is thus further reason to anticipate high comorbidity of language and speech deficits in adolescents with SLI, and to investigate interaction effects between speech production and language in this population.

Speech has been studied extensively in adults and in young children. In adults the focus has largely been on adults with overt neurological disorders such as aphasia or dysarthria, as well as speech errors in non-impaired adults in order to evaluate models of speech production. In children the focus has been on speech development in typically developing and disordered populations; speech disorders with clearly identified etiologies, such as cleft palate or cerebral palsy; as well as children with Developmental Phonological Disorders (DPDs), which are speech disorders of unknown origin (Shriberg, 2003). In most cases, the research has focused on children below the age of nine years, which is the age at which children are expected to have acquired all their speech sounds. Speech production in adolescence has been studied in terms of kinematic studies of typically developing adolescents (e.g. Walsh & Smith, 2002), as well as in reading disordered populations (Kamhi & Catts, 1986) or individuals with a history of DPDs (Lewis & Freebairn, 1992). Speech production abilities in language impaired individuals without overt neurological impairment has not received much research attention, yet such children make up an increasing part of speech-language pathologists' caseload.

1.2 Specific Language Impairment

Specific language impairment (SLI) is one of the most common and best-described paediatric language disorders. It refers to significant limitations of language learning without an overt cause such as autism, developmental delay or gross neurological impairment. This developmental disorder thus primarily affects language.

The prevalence of SLI is estimated at approximately 7% (Leonard, 1998; Tomblin, Records et al 1997), hence children with SLI constitute a large portion of the caseload of speech-language pathologists. In order for clinicians to provide appropriate and effective intervention, it is important to have a good understanding of the nature and clinical presentation of SLI as it affects all aspects of communication.

As will be seen in Chapter 3, SLI has been well-described in terms of its linguistic and processing characteristics, but the majority of studies in the area of SLI

have focused on describing the language characteristics of children between the ages of four and twelve years of age (Heilmann, 2004 in Miller & Fletcher, 2005). SLI has not been studied extensively in the adolescent population. Where adolescents with SLI have been researched, areas such as discourse, social skills or adjustment and literacy abilities, rather than speech output, were targeted. Similarly, while receptive phonology, morphosyntax, semantics, pragmatics, auditory processing and auditory memory have received substantial research attention, expressive phonology has been the focus of far fewer studies, and has not previously been investigated in adolescents with SLI.

The SLI population is not homogeneous. Since SLI is identified largely through exclusionary criteria, the SLI population is diverse. As is discussed in Chapter 3, several researchers have attempted to describe subtypes of SLI by categorizing differential impairments of expressive versus receptive abilities, or profiles of deficits with regard to phonology, morphology, syntax, semantics, pragmatics and memory. However, at present there is no widely accepted classification of SLI subtypes (Garman, James & Stojanovik, 2005).

For some children with the disorder, the linguistic deficits identified during the preschool years resolve before they enter school. However, as will be discussed in Chapter 4, for some individuals with SLI the disorder persists across the lifespan, extending beyond the preschool years into adolescence and adulthood. Consequently, some researchers differentiate the SLI population into resolving SLI and persistent SLI (e.g. Bishop & Edmundson, 1987; Stothard, Snowling, Bishop, Chipchase & Kaplan, 1998; Catts, Fey, Tomblin & Zhang, 2002; Bishop, Price, Dale & Plomin, 2003). Individuals with persistent SLI form the focus of the current study.

While morphosyntax and phonological memory deficits are recognized as key features of SLI (as described in Chapter 3), subtypes may present with differential impairment of a range of linguistic and processing areas. It is the hypothesis of this study that some subtypes present with speech impairment in addition to the other deficits, and that persistent SLI may be one such subtype.

Since SLI is such a diverse disorder, it is likely to be the result of more than one etiology, or have a multifactorial etiology. As is discussed in Chapter 3, thus far risk factors have been investigated largely in preschool or young school-aged children with SLI. In these populations, SLI frequently appears to have a genetic basis. However, little is known about risk factors specific to different subtypes. It is possible that persistent SLI, which is presumably a more severe manifestation of the disorder, may be linked to additional or alternative risk factors, such as factors during pregnancy, birth and early development. Furthermore, the effect of risk factors such as otitis media with effusion, which has sometimes been implicated in speech deficits; and Attention Deficit (Hyperactivity) Disorder, which is often associated with language impairment (Redmond & Rice, 1998), have not been investigated in adolescents with persistent SLI. Since attention is an important resource for language processing, this is an important aspect to consider.

This study proposes that, for at least some subtypes, speech production and motoric deficits contribute to the processing limitations seen in SLI. Much has been written about the nature of SLI, and many explanatory theories have been proposed. One such explanation views SLI as the result of a limited capacity system, where deficits in specific mechanisms and resource limitations interact to affect the functional capacity of the language processing system (e.g. Johnson, 1992; Fazio, 1998; Montgomery, 2002a). Explanatory accounts of SLI have focused largely on the linguistic and higher level processing abilities of this population. The potential impact of speech production deficits has usually been discounted. However, within an information processing model of language production, speech production forms a crucial component of language production.

Information processing accounts of SLI have considered both structural and functional accounts (Hanson & Montgomery, 2002). Within a structural account, it is thought that certain components of information processing, for example, phonological memory, have reduced capacity, thus impacting on the overall processing of language. In contrast, functional accounts emphasize the speed and efficiency of processing.

The current study, with its emphasis on one component of language processing (phonological output), thus could fit into a structural account of information processing deficits in SLI. However, clinical experience suggests that the speech deficits in adolescents with SLI are subtle, often consisting of inconsistent, context-dependent errors. Hence the speech deficits may be related, in part, to automaticity, which is defined as the ease or efficiency with which knowledge can be retrieved or manipulated (Field, 2004). The hypothesis is that speech production as a resource in the information processing chain may be compromised in adolescents with SLI, thus requiring more attentional resources than in typically developing adolescents. Hence, reduced capacity in the speech production component may impact on other aspects of information processing and consequently reduce the overall functional capacity of the language processing system.

The study has therefore adopted a processing limitations explanation of SLI (see Figure 3-2), but has placed special emphasis on the potential impact of motoric and speech production limitations on information processing abilities, without negating the importance of other aspects of processing.

The study has also adopted a threshold effect approach. Gillam, Hoffman, Marler and Wynn-Dancy (2002) proposed that subtle deficits throughout the language processing system interact, and that limitations at one level would affect processing at another level (the threshold effect). It is proposed in this study that for many children with SLI, phonological output, involving both lexicalization and the motoric component of speech production, is one of these subtle deficits, which interacts with other deficits throughout the language processing system, resulting in inefficient or slower processing of language. Thus, for at least some individuals with SLI, the surface symptoms thought to be typical of SLI may result from the interaction of mild speech production deficits with other deficits.

Recent literature in the area of SLI has placed much emphasis on phonological memory as measured by nonword repetition as one of the key deficits in SLI. However, nonword repetition is reliant on speech output. It is possible that verbal output tasks such as nonword repetition are affected not only by the construct under

investigation (phonological memory in this case) but also by speech output factors. It is therefore important to establish whether impaired speech output is frequently part of the clinical picture of SLI, as this has implications for the interpretation of performance on nonword repetition tasks.

1.3 Adolescence

With the recent emphasis on the speech-language pathologist's role in dealing with written language disorders, adolescents are increasingly forming part of clinicians' caseloads. Compared to the research available on younger clinical populations, adolescents with language disorders are poorly researched, leaving clinicians with little empirical evidence on which to base intervention. It is therefore important to expand our body of knowledge regarding adolescents with SLI.

As was discussed above, for many children with SLI, the disorder does not resolve, but persists into adolescence and adulthood. Similarly, phonological disorders may persist beyond the early school years (Pascoe, Stackhouse & Wells, 2006).

Adolescence provides a unique opportunity to study speech output, particularly the interaction between speech and language disorders. Adolescence represents the midpoint between the rapid development of speech and language in early childhood, and the mastery displayed by adults. Most studies investigating speech production in SLI have focused on preschool populations, the traditional territory for the investigation of developmental phonological disorders (DPDs). However, in such young children there are a number of unstable variables which could impact on speech production. The first variable reflects the fact that the child's phonetic inventory is often not complete until the age of seven or eight years. The phonemic repertoire of preschooler is thus dynamic, with new phonemes being added and production of all phonemes becoming more consistent across phonetic contexts. Secondly, the physical structures required for speech are undergoing rapid growth and development during this stage, requiring the child to adapt articulatory programs to accommodate changes in the size and relationship of articulators.

In preschoolers, speech errors may reflect protracted phonological development (which may resolve) or difficulties in adapting to physical changes in articulators. By adolescence, all speech sounds should have been acquired and stabilised and it is rare to find an adolescent with consistent speech errors. At the same time, physical growth of the vocal tract is largely complete by the onset of adolescence (Kent, 1999). Consequently, any speech difficulties noted in adolescents with SLI are likely to reflect an entrenched deficit in speech production, rather than the impact of developmental variables.

In the preschool population, it is not only the sound system that is developing rapidly, but also language. During this stage of rapid development, it may be difficult to isolate speech variables from language variables, particularly in the area of morphosyntax. In any assessment task requiring verbal output, the linguistic complexity of the utterance may constrain speech production (or vice versa). In contrast, by adolescence language development is much more mature, with morphological development being largely complete. It may therefore be easier to isolate speech variables from language variables, by assessing speech stimuli that are well within the adolescents' range of linguistic competence.

Adolescence therefore represents the midpoint on a continuum of development between childhood and adulthood. The developmental variables affecting children are less prominent during adolescence, yet the development is not complete. Adolescence thus provides a unique opportunity to investigate speech development in an immature system, while controlling some of the factors affecting research into speech production in younger children.

1.4 Rationale for the Study

In summary, the rationale for this study comes from several sources:

- Adolescents are increasingly forming part of the clinical caseload of speech-language pathologists, and as such, it is important to describe the presence and nature of speech and language disorders, as well as interactions between speech and language disorders, in this age group.

- Specific language impairment (SLI) is not just specific to the language system. While the cognitive and processing characteristics of the SLI population have been investigated extensively, less is known about the motoric and speech abilities of individuals with SLI.
- Phonological output forms an important part of the language processing chain, yet has not been adequately investigated in adolescents with SLI. If phonological output is compromised, either with regard to motoric output or aspects of lexicalization, it may result in a threshold effect, impacting on other language processing mechanisms. Consequently, speech deficits may impact on any verbal output task used in clinical practice or in research.
- Speech and language deficits frequently co-occur, thus it can be anticipated that many adolescents with SLI had speech deficits as preschoolers. Speech deficits often persist in the form of inconsistent, context-dependent errors, thus many adolescents with SLI may still present with speech deficits.
- Risk factors for persistent SLI have not been investigated in any detail, nor have risk factors associated with potential speech deficits in this population been investigated.
- Adolescence provides a unique opportunity to investigate speech production and speech deficits in a developing system, without the complicating variables present in early childhood.

1.5 Outline of Chapters

Chapter 2 defines and outlines speech production and speech disorders. Speech is defined and models used to explain the speech production process are presented, with specific focus on the stages of lexicalisation and planning. Models of sensorimotor speech production and models of lexicalization are described and discussed in order to provide a framework for the analysis of speech deficits in adolescents with SLI. Thereafter speech disorders are described with an emphasis on Developmental Phonological Disorders (DPDs), while the various classification systems used for DPDs are critically evaluated in relation to the purposes of this

study. Explanations for DPDs are considered in relation to adolescents with SLI and the hypothesized speech deficits expected in this population, while the potential long-term consequences of DPDs are presented. Finally, speech errors are discussed in terms of factors affecting the production of errors which have to be considered in developing an assessment tool for speech deficits in adolescents with SLI.

Chapter 3 defines and describes SLI in terms of its linguistic and nonlinguistic characteristics. These linguistic deficits could impact on aspects of lexicalization during the production of speech. The fact that SLI is not specific to language, but could also involve subtle neurological and motoric components which could contribute to speech deficits is highlighted, as is the fact that SLI is a heterogeneous disorder with much inter-individual variation. Explanations of SLI are considered, with emphasis on a general processing limitations account of SLI. Thus the concepts of a limited capacity system, models of information processing, processing speed, efficiency and processing trade-offs and automaticity are discussed in relation to the hypothesized impact of speech deficits on language processing in SLI. Emphasis is placed on the possibility of a threshold effect, where subtle deficits in one or more areas (including speech production) can compromise processing in other areas. Finally, this chapter considers risk factors for SLI, with emphasis on those risk factors which could pertain to a persistent SLI subgroup and/or which could impact on speech development and production in this population.

Chapter 4 focuses on speech development and production in adolescents with persistent SLI. Language development and deficits in adolescents with SLI is discussed, as is speech development and disorders. Potential factors related to the interaction of linguistic and speech deficits in this population are highlighted. Consequently, interactions between speech and language are also considered. Phonological memory is considered to be one of the most common underlying deficits in SLI, thus interactions among speech, language and memory are also discussed in relation to language processing. Specifically, the potential impact of speech deficits on verbal output tasks such as nonword repetition, one of the most frequently used tasks in researching SLI, is considered.

In each background chapter (Chapters 2-4), methodological considerations are summarized and implications for the present study highlighted.

Chapter 5 raises conceptual and methodological issues related to the study of speech deficits in adolescents with SLI. Firstly, the difficulties in operationalising the definition of SLI in order to select adolescent participants for this study are discussed and solutions are considered. Secondly, the development of an instrument, the Speech Assessment Battery (SAB), to assess speech deficits in adolescents is discussed in relation to a model developed to select tasks and analyse errors. Finally, in view of the clinical perspectives guiding the development of this study, issues regarding clinical versus research significance are discussed briefly in relation to the evaluation of results for this study.

Chapter 6 describes the method used for this study. It lists the aims of the study and describes the research design selected. Participants are described in terms of selection criteria and selection procedures. The instrumentation used to investigate speech deficits and related risk factors in adolescents with SLI is described. Finally, the methods used to collect and analyse the data are described. Ethical considerations are raised throughout this chapter.

Chapter 7 describes and discusses the results of the study in accordance with the aims. Thus the performance of adolescents with SLI on a Speech Assessment Battery (SAB) is compared to that of typically developing (TD) adolescents. The neuromotor functioning of the two groups is also compared. The usefulness of the SAB as an index to rule in or rule out SLI is discussed. Finally, risk factors associated with poor speech production in adolescents with SLI are discussed.

Chapter 8 provides a general discussion of the results of the study, linking results to current theories of speech production and explanatory models of SLI. Possible explanations for poor speech abilities in adolescents with SLI are discussed. Thereafter the implications of speech deficits in adolescents with SLI are considered with reference to explanations of SLI, interactions with language factors in SLI, and diagnostic criteria for SLI. Emphasis is placed on the threshold effect in terms of the potential interaction of speech production deficits with other language processing

deficits. In view of the findings of the study, a revised description of the nature of SLI in adolescence is provided. Risk factors specific to persistent SLI are considered. The assessment tool developed for this study, the Speech Assessment Battery is evaluated in terms of its clinical utility. Finally, limitations of the study are identified and clinical and research implications are considered.

2 Speech Production and Speech Disorders

Speech is one of the most complex cognitive operations that human beings perform (Field, 2004). This chapter will consider speech production by providing definitions related to the topic and discussing models explaining speech production, before considering the comorbidity of speech and language disorders. Thereafter Developmental Phonological Disorders (DPDs), the most likely type of speech disorder to occur in children with SLI, will be described and discussed with reference to the classification of DPDs, explanations for DPDs and the likely consequences of DPDs. Finally speech errors, particularly those occurring in unimpaired populations will be discussed as these are the types of errors likely to occur in the SLI population.

2.1 Definitions

Speech is the externalized expression of language (van der Merwe, 1997) and involves the development and control of skilled movement patterns (Ballard, Robin, Woodworth & Zimba, 2001). Speech production results from movements of the lips, tongue, jaw, velum, vocal folds and respiratory system (Caruso & Strand, 1999), involving the coordination of about 100 muscles at a speed that enables about 15 speech sounds to be produced every second (Field, 2004). As such it requires coordination and complex interactions among the respiratory, laryngeal and articulatory subsystems (Walsh & Smith, 2002). In order to produce intelligible speech and avoid speech errors, precise timing and accurate positioning of structures within the vocal tract are required (Caruso & Strand, 1999). Motoric deficits can therefore impact on speech production.

A phonological disorder affects a speaker's production and/or mental representation of speech sounds of the target language (Gierut, 1998). There are thus two components that may be affected. The first is a phonetic component, where the disorder may reflect an inability to articulate speech sounds, thus involving a motoric component (Gierut, 1998). The second is a linguistic component, where phonological processing is the end-stage of the cognitive-linguistic component of production, whereby the speaker selects phonemic elements and accomplishes their order by

applying the phonological rules of the language only after a message is conceived, semantic elements are selected, words are arranged in proper syntactic order, and the utterance is appropriately tailored to the communicative situation by the speaker, taking pragmatics into consideration (Haynes & Pindzola, 2004). However, as Bernthal and Bankson (1998, p.305) stated: "Although it is convenient to dichotomise the motor and linguistic aspects of phonology for organization purposes, normal phonological use obviously involves both the production of sounds at a motor level and their use in accordance with the rules of the language. Thus the two skills are intertwined and may be described as two sides of the same coin." The current study therefore uses the terms *phonological disorder* or *phonological output* to refer to both motoric and linguistic aspects of production. The term *speech output* is used to refer specifically to the motoric component of production.

Speech motor control can be defined as "…the systems and strategies that regulate the production of speech, including the planning and preparation of movements (sometimes called motor programming) and the execution of movement plans to result in muscle contractions and structural displacements" (Kent, 2000, p. 391). Speech motor control has traditionally been distinguished from phonologic operations. However, recently some phonologic theories have presented a deliberate blurring of the boundaries between phonologic representation and motor functions (Kent, 2000).

Motor speech production and disorders have been studied extensively in adults, but much less is known about the development of motor speech abilities. Many important fundamental issues underlying the acquisition of speech motor control and the development of motor speech disorders is still a matter of speculation (Caruso & Strand, 1999). For example, little is known about the interaction between linguistic and motor issues (Caruso & Strand, 1999) or about the way the respiratory, laryngeal and articulatory subsystems influence each other's development (Thelen & Smith, 1998 in Walsh & Smith, 2002).

2.2 Speech Production: Explanatory Models

The current study aimed to evaluate speech production errors in adolescents with SLI. In order to understand such errors, it is important to consider models of speech production which may serve to predict and explain such errors. In the section below a number of models of speech production will be considered, while focusing primarily on the components or stages common to a number of models.

Within a resource-limited system, it is important to consider that speech is a mixture of voluntary activity (at the highest levels of input) and automatic activity (at the lowest level) (Garman, 1990). The voluntary activity would be resource-demanding with regard to working memory and attention, and is therefore at-risk in children with SLI who are thought to have processing limitations (see Chapter 3). At the same time, as will be discussed in Chapter 4, in adolescents with SLI the lowest levels of speech processing may not have attained the required level of automaticity as the system is a) still developing, and b) may be affected by motoric deficits.

Field (2004) proposed that models of speech production should incorporate a number of stages to describe how a speaker assembles an utterance (see Figure 2-1). Field's stages will be used as a framework in which to discuss various models of speech production. A number of models can fit into this framework, including models of sensorimotor speech production (van der Merwe, 1997; Caruso & Strand, 1999; Owens, Metz & Haas, 2003), models of lexicalization (Laver, 1980; Garman, 1990; Levelt, 1992; Dell & O'Sheaghda, 1992), and models of speech processing (Stackhouse & Wells, 1997).

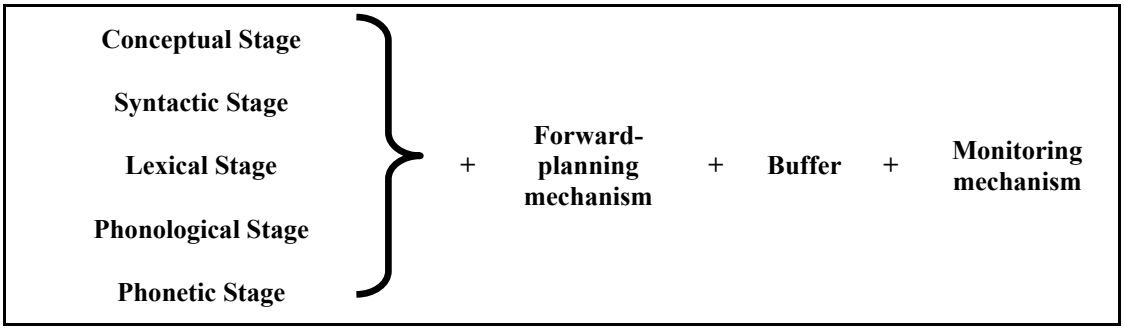

Figure 2-1: Field's (2004) proposed framework for models of speech production.

2.2.1 Conceptual Stage

The conceptual stage identifies the proposition to be expressed in an abstract form (Field, 2004). At a cognitive level a person has an idea to communicate, which must be transformed into a symbol that a listener can understand (van der Merwe, 1997). Thus language formulation begins at the point where linguistic processes interact with cognitive processes (Caruso & Strand, 1999). In order to develop a phonological representation, a process of lexicalization has to occur, where conceptual representations are transformed into phonological representations. Two components are involved in formulating an utterance: the generation of meaning and syntactic structure, and creation of its form (Meyer, 1992). This study has focused on the creation of form, thus semantic and syntactic components of this process will not be discussed in detail, nor will the uncertainty regarding the relationship between syntax and lexis be discussed. However, in view of the well-documented syntactic and semantic deficits of the SLI population, it can be anticipated that they may experience difficulty at this level.

Lexicalisation: Syntactic, Semantic and Phonological Stages

The syntactic stage involves the selection of an appropriate frame into which words are to be inserted, while the lexical stage involves a meaning-driven search of the lexicon, supported by cues as to the form of the target word (Field, 2004). Finally, the phonological stage converts the abstract information gathered so far into a speech-like form (Field, 2004). There is uncertainty regarding the relationship between the lexical and syntactical stages. Some models suggest that these stages occur sequentially (e.g. Levelt, 1989; Dell & Reich, 1980), while others place the two processes in parallel (Garrett, 1988 in Field, 2004; Garman, 1990). For the current study, the lexical and syntactic stages were not investigated: only the phonological and phonetic stages were considered.

Typically, models of lexicalization involve three levels: Conceptual representations, lemmas, and lexemes. Lemmas are linguistic units connected with grammatical specifications of words (Arnaud, 1999). Lexemes are phonological representations of the forms of words stored in the mental lexicon, including

information about the segments, specification of their order (Arnaud, 1999), and metrical information (Levelt, 1992). Models differ in their conceptualization of the direction of processing through these levels (unidirectional or bidirectional), and their view of the system as being modular or interactive. Levelt's (1992) discrete two-stage model and Dell's connectionist model (Dell & O'Sheaghdha, 1992) will be discussed briefly.

Levelt (1992) proposed a modular model where transmission of activation is feed-forward only. Two stages occur. Firstly, the conceptual level activates a single lemma (Arnaud, 1999), which is referred to as lexical selection (Levelt, 1992). The lemma contains specific semantic and syntactic information (Gagnon, Schwartz, Martin, Dell & Saffran, 1997), but is unspecified in terms of phonological form. This process can also be referred to as grammatical encoding, where the message is transformed into a hierarchical organization of syntactic phrases, containing lemmas. Secondly, once the lemma has been activated, it in turn activates the lexeme level (Arnaud, 1999). The latter process is referred to as phonological encoding, computing the phonetic shape from the selected item's phonological code stored in the mental lexicon (Levelt, 1992). Phonological encoding can also be defined as the conversion of a lexically/morphologically defined representation of the intended utterance, into a fully phonologically specified representation (Wilshire, 1999).

Levelt (1992) and Levelt and Wheeldon (1994) provided a detailed description of phonological encoding, i.e. the transformation of lemmas into lexemes. The activated lemma would in turn activate the selected word's lexeme. The model distinguished between segmental and metrical form. Segmental information refers to the phonemic structure, which is composed of consonants, vowels, diphthongs and so forth. Metrical information specifies the word's frame, in terms of the number of syllables and the lexical stress level of successive syllables. Metrical information is retrieved independently from segmental information, hence one can recall a word's length and stress pattern even when one cannot remember the sound (segment) structure. Metrical spell-out results in phonological word formation, which is combined with segmental information in a segment-to-frame association, where spelled-out segments

are associated to the metrical frame of the corresponding phonological word. The next step is the retrieval of syllable gesture scores.

Important for the current study, is Levelt and Wheeldon's (1994) suggestion that there is a mental syllabary, with most syllables being highly overlearned articulatory gestures. Levelt (1992) suggested that these syllable templates can be motor instructions for complex articulatory gestures. Individuals would have a store of syllable gestures for regularly used syllables. Syllable gesture scores are transmitted to the articulatory network for realization of the word. Children are likely to have smaller mental syllabary than adults. When children are required to repeat nonwords containing unfamiliar syllables, they may therefore not be able to draw on this mental syllabary, thus requiring more conscious control at this level.

There is therefore no direct link between the lexeme and the conceptual level in Levelt's model. Within each level, there is competition among units. Speech errors occur when semantic or phonological units close to the target are retrieved because they become more highly activated than the target. Once phonological encoding is complete, a phonetic or articulatory program is produced (roughly equivalent to planning and programming in the sensorimotor models described below).

In contrast to Levelt's discrete two-stage model, connectionist or spreading activation models consist of feedforward only activation (cascade models) (Humphreys, Riddoch & Quinlan, 1988 in Arnaud, 1999), which have not received much support; and interactive models, with both forward and backward spreading activation, such as those proposed by Dell and colleagues (e.g. Dell & Reich, 1980; Dell & O'Sheaghdha, 1992). These models are neural-like, incorporating large arrays of simple units which are heavily interconnected, and have simultaneous interaction of large numbers of units (Nadeau, 2001).

In Dell's model (Dell & Reich, 1980; Dell & O'Sheaghdha, 1992; Roelofs, 1992; Gagnon, Schwartz, Martin, Dell & Saffran, 1997), lexical information is represented in hierarchical networks of nodes with a bidirectional flow of information. Three levels of nodes exist: semantic, lemma and phoneme nodes, which have bidirectional connections among levels or nodes. Once semantic nodes are activated, they would

activate the corresponding lemma nodes, which in turn would activate the relevant phoneme nodes. At both the lemma and the phoneme levels, the most highly activated node would be retrieved, whether it is the correct one or not. At each of these levels, nodes would compete for selection. Dell proposed that at the lemma level semantic competitors are activated by the top-down spread of activation of semantic features, which would activate nontarget nodes that share the same semantic features as the target node. At the same time, phonological competitors are activated by bottom-up feedback from target phonemes to all nontarget lemma nodes connected to them. According to Dell, errors can occur when there is a faster than normal rate of activation decay, where nodes decay to a resting level of activation too quickly. Nodes which were activated early, including the target node, would be disadvantaged, resulting in selection of semantically or phonologically related nodes which were activated later.

The occurrence of both anticipatory and perseverative errors has reinforced the concept that as the brain processes phonemes, a number are maintained in a similar state of activity for some time, even though they occur sequentially in the output phoneme stream (Nadeau, 2001). Consequently, a given phoneme may have as much opportunity to influence phonemes later in the stream (perseverative errors) as there is opportunity for later phonemes to influence it (anticipatory errors). Dell's model is also thought to explain lexical effects, where errors tend to produce real words rather than nonwords; and similarity effects, where repeated phonemes tend to induce misordering of sounds around them.

The current study hypothesizes that anticipatory and perseverative substitution errors will be common in the SLI population because of motoric limitations (see Chapter 3) and the greater likelihood of decay in the buffer (see below), but that lexical effects will be less common because of the linguistic deficits in SLI which would impact on the effectiveness of the monitoring function.

Children with phonological, syntactic or semantic deficits are likely to have difficulties at this stage. The errors described as typical of impairment at this stage, transpositions and phoneme substitutions (van der Merwe, 1997), are very similar to

errors noted in clinical practice on tasks assessing phonological awareness and auditory memory in children with language impairment. As will be discussed in Chapter 4, there is an interaction between language and speech, where increased linguistic demands affect misarticulations and fluency. Children with SLI may be particularly vulnerable at this stage of speech production, as their limited semantic, syntactic and phonological knowledge may impact on resource allocation, which could detract from phonological planning, resulting in speech errors.

2.2.2 Phonetic Stage

The phonetic stage prepares instructions to the muscles controlling the articulators (Field, 2004). Models of (sensori)motor speech production would expand this last stage to include motor planning, motor programming and motor execution.

Motor Planning

Motor planning of speech output serves to transform cognitive/linguistic processes to speech movements. The goal is to produce movements of the vocal tract which would result in intelligible speech (Caruso & Strand, 1999), which requires a motor plan, specifying the motor goals necessary to guide speech movements (van der Merwe, 1997). This plan would have to include both the spatial configuration or articulatory posture aligned with the acoustic goal, and the articulatory movement dynamics required to reach that target (Caruso & Strand, 1999; van der Merwe, 1997).

Planning is likely to involve templates (Caruso & Strand, 1999) or core motor plans (van der Merwe, 1997). It has been proposed that experienced speakers (adults) have developed templates (Caruso & Strand, 1999) or core motor plans (van der Merwe, 1997) for speech production, which facilitate the sensorimotor planning of speech motor output. These templates or core motor plans with spatial and temporal specifications for each sound would reduce the magnitude of consciousness needed for selected events prior to speech production, thus facilitating speech planning, or freeing resources for other aspects of processing. These core motor plans can be

adapted, based on the phonetic context of an utterance and the need for coarticulation, as well as rate of speech.

The core motor plan is attained during the development of speech, when the motor specifications and sensory model are stored in sensorimotor memory (van der Merwe, 1997). While this core motor plan is being mastered, proprioceptive, tactile and auditory feedback is implemented. However, in view of the protracted biomechanical and neural development of the speech mechanism (see Chapter 4), it may only be during adolescence that core motor plans can be finalized, which suggests that children are more dependent on feedback than adults. Thus motor planning in children may require more conscious effort, placing greater demands on resource allocation. With reference to Caruso and Strand's concept of templates, the implication is that children (and adolescents), as less experienced speakers, may have fewer templates, or less well-specified templates, thus requiring a more conscious level of effort during the planning of speech movements. Should a child or adolescent be asked to perform a task which makes substantial demands on available resources, he or she may not have sufficient resources to allocate to the planning of speech movements, which may compromise the speech production process.

Van der Merwe (1997) has suggested that children with developmental articulation errors had core motor plans for the production of error sounds that differed from those of other speakers in their communication environment. The question would remain, however, as to why this core motor plan was different, and whether it is ever fully corrected. Other speech symptoms at this level would also include slow, struggling speech with distortion and apparent substitution, which are characteristic of apraxia of speech (Wertz, 1985; McNeil, Robin & Schmidt, 1997).

Once the core motor plan is recalled, specific motor goals such as lip rounding or jaw depression are identified for each phoneme and fed forward to the motor programming system (van der Merwe, 1997).

Motor Programming

A motor program is a set of muscle commands which are structured before a movement begins, and which can be delivered without reference to external feedback, although feedback can be used to update the program if necessary (van der Merwe, 1997). Programming primarily involves articulatory timing and positioning (Caruso & Strand, 1999), incorporating muscle tone, movement direction, force, range, rate, timing relations, and interstructure relations (van der Merwe, 1997; Caruso & Strand, 1999).

A disorder of motor programming would result in speech symptoms which include distortion, impaired speech rate, and/or problems in the initiation of movement (van der Merwe, 1997), which are typically associated with dysarthria (Wertz, 1985; McNeil, Robin & Schmidt, 1997). The motor impairments described in children with SLI (Hill, 2001) may impact on motor programming and execution. The deficits are probably sufficiently mild to allow for compensation within a redundant system, but speech production may be more resource-demanding for these children. The reduced speech rate noted in individuals with SLI (see Chapter 3) could be related to motor programming difficulties, although no empirical evidence exists for this hypothesis. It is equally possible that rate of speech is affected by processing limitations throughout the cognitive-linguistic system.

Motor Execution

Execution involves the realization of the planned and programmed movements (van der Merwe, 1997; Caruso & Strand, 1999), where ultimately properly timed commands result in muscle movements. During speech development or in unfamiliar speech acts, execution may be dependent on more extensive control processes, including feedback from the programming level, and tactile-kinesthetic and auditory feedback (van der Merwe, 1997). Impairment at this stage is likely to result in the type of speech symptoms typical of dysarthria (Darley, Aronson & Brown, 1975).

Language impaired children with poor auditory perceptual skills may not be able to make full use of auditory feedback as a monitoring system, and would thus be more reliant on other forms of feedback. The implication is also that more resources

are required for execution of the speech act in children, or when producing unfamiliar words (such as nonwords).

2.2.3 Forward-Planning

The forward-planning mechanism occurs at discourse level and assists, for example, in determining which parts of the message should receive informational focus through intonation (Field, 2004). Since this study did not focus on discourse tasks, this area will not be discussed further.

2.2.4 Buffer

The buffer holds the whole of a planned clause while the clause is being articulated (Field, 2004) and thus forms part of working memory. There is some evidence that speech needs to be pre-assembled in clauses before it is produced in order to impose intonation patterns upon an utterance, which provides support for the concept of a mental buffer in which to store a blueprint of the upcoming utterance before it is articulated (Field, 2004). The buffer could also form part of the monitoring process, as it enables a review of the pre-assembled sequence before articulation takes place, although Laver (1980) proposed that a linguistic program is only stored in the buffer once the monitoring function is satisfied of its adequacy to express an idea. As will be discussed in Chapter 3, children with SLI often have an impaired working memory, suggesting that this stage of speech production may be affected.

2.2.5 Monitoring Mechanism

The monitoring mechanism enables speakers to check their speech for errors or lack of clarity (Field, 2004)[1]. It appears likely that self-monitoring occurs both at a pre-articulatory level, where the speaker checks that the speech plan has been correctly assembled before putting it into effect; and while speech is being uttered (Laver, 1980; Field, 2004). However, there is much debate about exactly how and

[1] Self-monitoring can be defined as a process of checking one's own language productions to ensure they are a) accurate in terms of phonology, lexis and syntax; b) appropriate in terms of register; c) at an acceptable level of speed, loudness and precision; d) likely to be clear to the listener; and e) likely to have the right rhetorical impact (Field, 2004).

when monitoring occurs. Important for this study is the fact that monitoring requires attention. It can be assumed that the more errors are detected and corrected at a pre-articulatory level, the more attention is required. Laver (1980) proposed that fluctuations in attention could be responsible for erratic performance.

Both feedforward and feedback mechanisms have been proposed, which are probably utilized at multiple levels of speech processing (Laver, 1980; van der Merwe, 1997; Owens, Metz & Haas, 2003). Some models have disregarded the influence of interactions with cognitive or linguistic processes during feedforward and feedback control. For example, van der Merwe (1997) proposed that feedback as a consequence of speech production could involve auditory, tactile and proprioceptive feedback, with proprioceptive feedback being the most important to adults, as it occurs faster than auditory or tactile feedback. In her model, information is not only fed back from the periphery, but information is relayed from motor to sensory areas through reciprocal connections between sensory and motor areas of the cerebral cortex. Strand and McCauley (1999), whose model is largely based on that of van der Merwe, acknowledged that this interaction of sensorimotor processes is fundamental to articulatory performance. However, they also stressed the importance of global interactions among cognitive, linguistic and motor processing, stating that language and motor processes not only interact, but are so inextricably linked that they cannot realistically be separated. In view of the interactions among speech, language and memory which will be discussed in Chapter 4, the latter view is felt to be more appropriate to adolescents with SLI, than a model which does not consider linguistic processes.

Levelt (1989, 1992) proposed the existence of postlexical processes, where the speaker monitors his lexical productions to some extent, and can intercept imminent errors before they are overtly produced (thus similar to the feedforward and feedback processes suggested for sensorimotor speech production). Similarly, it has been proposed that each level or subsystem in translation is served by a control process which checks the output in the subsystem it serves (Butterworth, 1992); and that an "editor" may monitor phonemic errors and suppress them prior to articulation.

A large number of overt errors are corrected (64% in Nooteboom's [1980] study). At the same time, the incidence of overt errors in speech is thought to be quite low (Laver, 1980), providing support for the presence of an integral monitoring mechanism. Monitoring and error detection is resource-limited (Oomen & Postma, 2002). Speech errors are therefore reduced and controlled, so that, as will be discussed below, certain error types are more likely than others. Audible speech output is therefore not necessarily an indication of the integrity of the system. Under conditions which are not resource-demanding, control processes may be able to correct a number of errors at the level of phonological encoding, before articulatory processes become involved; but under resource-demanding conditions, control processes may not be implemented as effectively, resulting in speech errors.

While many of the models mentioned above have aided our understanding of speech processing on a largely theoretical level and primarily with reference to adults, Stackhouse and Wells (1997) have proposed a model of speech processing in children which is linked directly to assessment and intervention, and is able, to some extent, to allow for prognostic statements. Their psycholinguistic model can be divided broadly into input, lexical representation and output. Lexical representation would be largely equivalent to the lexicalization process described above, with the addition of orthographic representation and motor programs. Stackhouse and Wells propose that the speaker has access to motor programs which are stored sets of instruction for the pronunciation of each word in the lexicon. This view contrasts somewhat with the authors presented above, who would argue that the unit of planning is either the sound (van der Merwe, 1997) or the syllable (e.g. Levelt, 1989), and there is little evidence to support the motor programs described by Stackhouse and Wells at a word level. The output section, relevant to this study, requires access to accurate motor programs, manipulation of phonological units, accurate articulation of real words and nonwords (i.e. with and without reference to lexical representations), and adequate sound production skills (structural and motoric aspects).

Any analysis of speech errors should consider explanatory models of speech production to determine the level at which breakdown is occurring, in order to

establish the origins of the errors and to determine appropriate intervention where necessary. The current study based its analysis of speech errors on the models described above, rather than on traditional analyses of paediatric speech disorders. The primary rationale for this decision is the fact that the focus of this study was an adolescent population, where the errors are no longer typical of younger children with Developmental Phonological Disorders. Nonetheless, it was thought that many of the adolescents in this study may originally have presented with DPDs, hence a discussion of this speech disorder is warranted. However, before presenting a discussion of DPDs, it is important to consider the comorbidity of language and speech disorders, with particular reference to SLI.

2.3 Comorbidity of Language and Speech Disorders

It is generally accepted that there is a high comorbidity of language and speech disorders, although there is much variability in comorbidity estimates. Some authors suggest that of children who are initially identified as having a phonological impairment, approximately one fifth to one third will also have language comprehension deficits, and 60-80% will have language production deficits (Shriberg & Kwiatkowski, 1994; Shriberg & Austin, 1998). Other studies have suggested that about 25% of kindergarten children with poor language abilities will also have significant speech problems (Tomblin, 1989) while 50% of children identified with moderate to severe phonological disorders also have poor language abilities (Lewis, 1996 in Rice et al, 1998). Overall, Shriberg and Austin (1998) reported that the studies they reviewed yielded an average comorbidity of 55.7% for children ascertained by speech, and 47.6% for children ascertained by language, with a range of 21-77%. Variables associated with the magnitude of comorbidity include language modality, where expressive language deficits are more likely to co-occur with speech disorders than receptive deficits, and language domain, with grammar deficits more likely to co-occur with speech deficits than vocabulary deficits (Shriberg & Austin, 1998).

However, more recently, it has been suggested that the comorbidity is lower than previously reported. Rice, Haney and Wexler (1998) have suggested that children with only language impairment may have been underrepresented in previous clinically ascertained samples, because of the referral bias for children with concomitant speech disorders. Some support for this viewpoint was provided by the large epidemiological study conducted by Tomblin and colleagues, which found that in the overall population of 6-year old children sampled, co-occurrence of SLI and speech disorders was estimated at 1.3%, while in the SLI group, 5-8% also presented with speech disorders (Shriberg, Tomblin & McSweeny, 1999). However, this study relied on the use of the Word Articulation subtest of the Test of Language Development-2: Primary (Newcomer & Hammill, 1988) to identify speech deficits. This test does not provide an in-depth assessment of articulation and may have missed mild or inconsistent speech deficits. Shriberg and Austin (1998) also reported that results from four comorbidity studies using Shriberg's Speech Disorders Classification System (SDCS) (see discussion below) suggested that comorbidity of speech-language disorders is lower than previously reported. Of significance for the current study, is the fact that the majority of comorbidity studies have investigated the 3-7 year age range, and there is scant data for older children.

Methodological differences among studies, with regard to the definition of speech or language disorder as well as the method of ascertainment of the disorders, can probably account for the large differences in reported comorbidity. Shriberg and Austin (1998) further suggested that comorbidity data obtained by clinical referral could be biased by social factors affecting sampling; that the social salience of speech versus language disorders could result in a greater likelihood of children being referred for speech disorders than mild language disorders; and that comorbidity is higher in children ascertained by speech disorder, as only children whose speech has not normalized, and are therefore more likely to have severe speech involvement, are eligible for inclusion. However, whatever the true comorbidity rate may be, the fact remains that children with SLI have a higher rate of speech disorders than the general population.

Studies on speech disorders in children with SLI have generally focused on phonological aspects, rather than articulatory-motor aspects, as it is postulated that children who have difficulty with the organisation and rule-governed nature of language, will have difficulty in generating and extrapolating phonological rules. Phonology is often limited in children with SLI although children with phonological disorders are only included in the SLI category if they also perform poorly on other language measures (Leonard, 1998). Leonard (1982) suggested that children with SLI may initially present with normal phonological errors, but that these errors persist beyond the acceptable developmental period.

In a review of literature, Leonard (1998) concluded that children with deficits in lexical skills and morphosyntax almost invariably have phonological deficits as well. This finding would support Bauman-Waengler's (1994) description regarding the interaction of different language domains during development. She proposed that the acquisition of vocabulary involves new sound sequences, requiring increased oral-motor control and improved timing skills, as well as internalisations of new phonological rules. Acquisition of morphology is also related to phonological growth, as the learning of specific morphological structures implies learning of phonological rules. It is therefore possible that phonological deficits could contribute to the morphosyntactic and lexical deficits seen in SLI. Consequently, it is important to consider the types of speech disorders that could occur in children with SLI.

2.4 Developmental Phonological Disorders (DPDs)

DPDs will be discussed with reference to the definition and classification of DPDs, some explanations for DPDs, and the likely consequences of DPDs.

2.4.1 Definition and Classification of DPDs

Speech sound disorders can be divided into two categories. One category involves motor speech disorders of clear neurogenic origin, which are further divided into the dysarthrias and apraxia of speech (McNeil, Robin & Schmidt, 1997)[2]. Since

[2] Dysarthria refers to a group of speech disorders resulting from disturbances in muscle control, involving weakness, slowness or incoordination of the speech mechanism due to damage to the central

this category relates to overt neurological dysfunction, it is not of relevance to the SLI population. The second category involves speech sound errors evident during speech development, which are not overtly of neurogenic origin.

Paediatric speech-sound disorders of unknown origin can be defined as a notable difference in the acquisition of speech sounds which cannot be attributed to significant impairment in structural, sensory, motor, cognitive or affective functioning (Shriberg, 1980), a definition containing similar exclusionary criteria as those considered in SLI. Since the early 1970s classificatory terms for this latter category have changed from *functional articulation disorder* to *developmental phonological disorder*, reflecting a theoretical shift towards a more linguistic perspective (Shriberg, 2003).

Prevalence of speech delay only in children ranges from 2.3-24.6% (Law et al, 2000), depending on the criteria used and the age group studied. In a large scale epidemiological survey in Ontario, Canada, Johnson et al (1999) reported a prevalence of 6.4% for speech-only impairments (articulation, voice and/or fluency) at age 5 years, while Shriberg, Tomblin and McSweeney (1999) reported that 3.8% of 6-year old children in an epidemiological study met the diagnostic criteria for Speech Delay[3]. More males than females are affected, with ratios of 1.5:1 to 3:1 reported (Felsenfeld, 2002).

Currently three types of classification systems are used for speech-sound disorders in children: linguistic descriptions, focusing on the phonological and phonetic constructs and principles underlying the pattern of speech error targets and error types; psycholinguistic and neurolinguistic approaches, focusing on the psycholinguistic loci (such as phonological awareness and working memory) and

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or peripheral nervous system or both (Darley, 1969 in Wertz, 1985). The term is used to cover isolated or coexisting motor disorders of respiration, phonation, articulation, resonance and prosody (Darley, Aronson & Brown, 1975). Apraxia of speech can be defined as a disruption of the programming of speech skills for the volitional production of speech sounds and their combination into sequences to form words (Wertz, 1985).

[3] Speech Delay is diagnosed in the presence of consonant substitutions and deletions characteristic of Ingram's (1976) *Phonological Stage II* that persist in conversational speech past 4 years of age (Shriberg, 2003).

neurolinguistic loci, obtained from kinematic, physiologic and imaging studies (i.e. proximal cause); and classification by etiological processes (distal cause).

The current study reflects an integration of all three of these classification systems. Speech errors present in adolescents with SLI will be explained in part with reference to linguistic descriptions, while psycholinguistic factors such as phonological awareness and working memory will also be explored in terms of their interaction with speech difficulties. Finally, etiological processes related to speech disorders in adolescents with SLI will be considered.

Literature in the field of SLI has tended simply to differentiate speech disorders into articulation and phonological disorders, where the term "articulation" primarily refers to the physical production of the sounds of speech (Field, 2004), while the term "phonology" is closely related to language. Both types of disorders have been identified in the SLI population. Articulation disorders are usually seen to involve a motoric component, resulting in an inability to articulate speech sounds or a phonetic disorder (Gierut, 1998). Phonology refers to the language-specific function of speech sounds, where the function of speech sounds is to establish meaningful units of language, such as morphemes or words (Bauman-Waengler, 1994). In a phonological disorder sound errors are assumed to be related to difficulties forming and accessing abstract representations of the sound structure of words (Munson, Bjorum & Windsor, 2003) with the result that phonological disorder is regarded as a functional linguistic disorder, rather than a speech disorder.

The distinction between articulation and phonology is quite broad, and may not be entirely accurate. While it is tempting to separate articulation disorders (motorically based errors) from phonological disorders (cognitively or linguistically based errors), the reality is that motor and linguistic aspects of speech production are intertwined, as speech obviously involves the production of sounds (motor) in accordance with the rules of a language (linguistic). It is therefore necessary to look at broader classification systems than a simple articulation/phonology distinction.

Recently, two classification systems have been proposed for paediatric speech sound disorders, which have application to children with SLI.

Dodd (1995b), using a linguistic, descriptive approach proposed four subtypes of speech disorder: 1) an articulation disorder, which is an inability to produce a perceptually acceptable version of a particular phoneme in any context; 2) delayed phonological acquisition, which describes the protracted use of phonological processes which commonly occur during normal development; 3) consistent deviant disorder, which involves the child's use of consistent non-developmental phonological rules; and 4) inconsistent disorder, which involves the use of speech errors which cannot be explained by the consistent application of phonological rules. These categories have been validated in subsequent studies (e.g. Fox, Dodd & Howard, 2002) and provide a useful approach to the description of observed symptomatology.

It is proposed that the first three categories could certainly explain some of the speech sound errors seen in preschool children with SLI, while the fourth category may describe the difficulties encountered by older children with SLI. Dodd (1995b) suggested that some inconsistent errors reflect that the child's phonological system is changing from the use of an error to correct production; or reflect incorrect perceptions or representations of words; or errors are influenced by linguistic load. However, some children present with inconsistent errors which cannot be explained by any of these factors. Dodd proposed that inconsistent deviant disorders are associated with a phonological planning deficit. As will be seen in the section discussing explanations for SLI (Chapter 3), all these potential explanations may apply to children with SLI.

In recent years, Shriberg and colleagues have developed an etiologically based classification system known as the Speech Disorders Classification System (SDCS) (Shriberg, 1993; Shriberg, Austin, Lewis, McSweeney & Wilson, 1997; Shriberg & Austin, 1998). The primary purpose of the SDCS is "… to classify a person's speech production status throughout the lifespan" (Shriberg et al, 1997, p. 723). The SDCS was thus particularly useful in the current study, as most classification systems for speech sound disorders focus either on the preschool and early school-age populations with developmental speech disorders, or on adults with acquired speech

disorders. Furthermore, Shriberg's (1980) definition of Developmental Phonological Disorders is very similar to that of SLI, thus facilitating the use of the SDCS with an SLI population.

Since its first development (Shriberg, 1993), much research has been done to extend and validate the SDCS[4]. However, it is recognized that the SDCS has limitations. In a recent study (Fox, Dodd & Howard, 2002), 59% of the participants with speech disorder could not be differentiated according to Shriberg's categories, which has significant implications for the clinical utility of the classification system. In the section below, the original SDCS will be presented.

The SDCS includes primary classification categories accounting for the number and type of speech errors, suspected etiological subtypes, and the course of the disorder (Shriberg & Austin, 1998). One of the four main subtypes is termed Developmental Phonological Disorders (DPD), which is the focus of the current study, and which is further divided into three descriptive subtypes, two of which are of relevance to this study. Firstly, Residual Errors (RE) are diagnosed in children over the age of 9 years, who still have speech errors. Two groups are distinguished: those with a history of speech delay (RE-A), and those with no history of speech delay (RE-B). Error patterns include residual common distortion errors and imprecise speech (e.g. omissions and substitutions). Secondly, Speech Delay (SD) is the classification used for children below the age of 9 years with persistent deletion and substitution errors, or atypical unintelligibility (below 75%) for their age.

Speech delay (SD), occurring in approximately 60% of preschoolers with DPD, was divided into four proposed etiological subtypes of DPD and a classification for children in special populations with known causes (Shriberg & Austin, 1998). Speech Delay related to otitis media with effusion (SD-OME) suggests that the possible origin of this type of SD is linguistic processing deficits associated with fluctuant conductive hearing loss due to early recurrent otitis media with effusion, and occurs in approximately 30% of preschoolers with speech delay. Speech Delay

[4] See Shriberg (1993); Shriberg (2003); Shriberg, Austin, Lewis, McSweeney & Wilson (1997); Shriberg, Campbell, et al (2003); Shriberg, Flipsen, Kwiatkowski and McSweeney (2003); Shriberg, Green, Campbell, McSweeney and Scheer (2003); and Shriberg, Kent et al (2003).

related to developmental apraxia of speech (SD-DAS) occurs in approximately 3-5% of children referred for speech disorder of unknown origin (Shriberg & Austin, 1998). Speech Delay with developmental psychosocial involvement (SD-DPI) is the most speculative of the SDCS subtypes and accounts for approximately 7% of children with speech delay. In this category it is proposed that psychosocial issues alone may be causally sufficient for speech delay in some children. Finally, Speech Delay in special populations refers to children who have developmentally related speech deficits in addition to their unique speech involvements.

It is the hypothesis of this study that many children with SLI may initially present with Speech Delay (similar to Dodd's categories) during the preschool years, while adolescents with SLI may present with Residual Errors, which may resemble Dodd's inconsistent group.

2.4.2 Explanations of Developmental Phonological Disorders

Several explanatory frameworks exist to account for the acquisition and persistence of speech-sound errors. Deficits have been proposed at a number of stages of processing, including auditory-perceptual, cognitive-memory or linguistic, and articulatory-motor processing (Dodd, 1995a; Shriberg, 2003). Dodd (1995a) suggested that different explanations hold for different children or possibly for different errors within the same child at different times. Thus some errors may be related to auditory misperception, although it has been demonstrated that not all children's speech errors can be attributed to misperceptions of words. Some errors can be attributed to poor oromotor skills; although again not all children's speech errors can be attributed to motor difficulty. A final group of errors may represent a cognitive-linguistic deficit, where speech errors reflect the children's implicit hypotheses about the speech-sound system of their language. In the section below, these explanatory frameworks will be discussed with reference to children with SLI.

Auditory Perceptual Deficits

The influence of the auditory temporal processing deficits that are characteristic of SLI on speech output cannot be discounted. Tallal and colleagues (e.g. Tallal &

Piercy, 1973, 1974; Tallal, 1976) have demonstrated that children with SLI do have specific difficulties with sounds of shorter duration and intensity, which lends some support for the idea that these auditory perceptual deficits may impact on speech production. However, it is unlikely that auditory processing deficits alone would account for the deficits seen in SLI. For example, it has often been observed that children with SLI can produce phoneme contrasts that they cannot perceive in experimental tasks (Leonard, 1998).

It is the view of the current study that auditory perceptual deficits, such as poor auditory discrimination may certainly contribute to some speech errors during the early stages of speech development. However, by adolescence the confusion caused by such misperceptions would largely have resolved. It is possible that the rapid auditory temporal processing deficits described by Tallal may add to the threshold effect (Gillam, Hoffman, Marler & Wynn-Dancy, 2002) in older children with SLI (which will be discussed in Chapter 3), by weakening yet another resource during linguistic processing, thus impacting on other aspects of processing. However, as the current study was concerned with speech output factors, the effect of input factors such as auditory perception was not investigated.

Cognitive-Memory or Linguistic Deficits

Cognitive and linguistic factors are likely to impact on the stage of systematic phonological development, which occurs between the ages of 18 months and 4 years in typically developing children (Vihman, 1988b). During this stage the child reorganizes the phonological system from word to segment (Vihman, 1988a), and develops a rule-governed phonological system (Yavaş, 1998). This stage of phonological development is closely linked to language development in terms of semantic and syntactic development (Bauman-Waengler, 1994; Yavaş, 1998), as well as cognitive development.

Children with SLI often demonstrate delayed or deviant phonological development during this stage (Leonard, 1998). While cognitive-linguistic factors are certainly of relevance to speech development in younger children with SLI, it is

thought that by adolescence the effect of such deficits on phonological output would have resolved in all but the most severely affected individuals. However, phonological awareness, which may be regarded as receptive phonological knowledge, is often impaired in children with SLI, and may continue to affect speech production in subtle ways.

There has been some suggestion that some of the speech production difficulties in children with SLI are related to difficulties with phonological awareness. For example, Foy and Mann (2001) found that children with impaired phonological awareness abilities presented with a different pattern of speech perception and articulation errors than children with strong phonological awareness abilities. They reported that impaired rhyme awareness was linked to syllable reduction and consonant cluster reduction errors. Edwards and Lahey (1998) as well as Bird, Bishop and Freeman (1995) have proposed that children with SLI rely on more holistic phonological representations than even younger normal children, and thus miss specific segmental contrasts. It therefore seems important to investigate phonological awareness abilities in a study on speech production in SLI.

Articulatory-Motor Deficits

Strict divisions between cognitive-linguistic and articulatory-motor deficits may be unnecessary and inappropriate. Deficits in the two areas may certainly co-occur or overlap. In the early days of the discipline of speech pathology, articulation was conceptualized as primarily a motor act. Until the early 1970s, assessment and treatment was focused on sensorimotor aspects of articulation. With the shift to a linguistic perspective in the mid-1970s, it is now widely acknowledged that linguistic activity contributes substantially to the articulatory process (Haynes & Pindzola, 2004), and assessment and treatment practices have increasingly emphasized the linguistic aspect of speech production. As Kent (2000) pointed out, one of the challenges in speech motor disorders is to distinguish between impairments of motor control and impairments of phonology.

However, Edwards, Fourakis, Beckman and Fox (1999) have criticized such a modular demarcation between "phonological knowledge" (a symbolic cognitive component) and "phonetic performance" (a purely mechanical perceptual and motor component). In a study evaluating perceptual and production knowledge in preschoolers, Edwards et al concluded that phonological knowledge is multifaceted, and that apparent deficits at one level can be linked to less robust representations at other levels. They proposed that phonological knowledge is a multilayered structure (rather than a dichotomous structure), including several different complex representational spaces, as well as the mappings among them. These spaces would include an acoustic/perceptual space, and articulatory/production space and the inverse mapping between production and perception. Such a conclusion would concur with Kent's (2000) proposal that impairments of motor control and impairments of phonology may coexist in some disorders.

There has been much debate whether speech problems reflect underlying difficulties in perceptual discrimination, linguistic knowledge, or motor limitations. Edwards et al's (1999) findings would suggest that such a division is not necessary. Children with phonological disorders may thus have deficits in the knowledge representations for speech perception as well as subtle motor knowledge deficits (as was shown in a number of studies reviewed by Edwards et al).

There is growing evidence that motor variables are relevant to children with developmental phonological disorders in the absence of apraxia or dysarthria (Strand & McCauley, 1999), since all children must overcome articulatory (motor) challenges in order to modify their phonetic and phonemic repertoires (Fletcher, 1992 in Strand & McCauley, 1999). As Haynes and Pindzola (2004) emphasized, motoric integrity is essential for normal speech production. For example, Bradford and Dodd (1996) reported that children in their inconsistent deviant phonology group showed isolated motor deficits. Specifically, they had difficulty with the execution of rapid gestures (oral and manual), rather than the execution of simple or sequenced movements. These difficulties have been interpreted as suggesting a planning deficit (although this group is still seen as distinct from a developmental verbal dyspraxia group). Even the

children in the delayed phonology group did not show a marked improvement across three imitations of a novel word, which Strand and McCauley (1999) interpreted as indicative of a difficulty in extracting motor commands for use in word production, and a possible lack of flexibility in the formulation of motor planning.

Apart from the subgroups identified by Bradford and Dodd, children with isolated misarticulations on sounds that are considered more difficult from a motor standpoint (e.g. /s/ and /r/), have traditionally been viewed as having isolated difficulties in learning the motor gestures required for consistent accurate production (Strand & McCauley, 1999). A study by Edwards, Fourakis, Beckman and Fox (1999) involving preschool children with phonological disorders, confirmed this view when it found that these children were less able to manoeuvre the jaw and tongue body separately, and that they used less controlled gestures from lingual consonants to vowels than their normal peers. Duffy (1995) also reported that many children with speech disorders demonstrate signs of neurologic dysfunction, even if these are not "hard" signs such as obvious paralysis and/or sensory deficits. Such subtle neurological deficits could impact on speech production.

There are thus subgroups of developmental speech impairment other than apraxia and dysarthria which would appear to have deficient motor performance or learning. However, it should be noted that studies regarding the potential relationship between speech-motor deficits and speech delay have yielded mixed results, regardless of whether an undifferentiated group or subtypes of speech delay were investigated (Flipsen, 2002).

It is postulated that the operating range for speech may be reduced in some children with SLI because of their motor impairments (see Chapter 3). Maximal limits of a given system provide an envelope, while the operating range is the part of the envelope typically used for a given task (Robin, Solomon, Moon & Folkins, 1997). Having a reduced envelope may not affect speech directly, but may make speech gestures more difficult to produce. Speakers with good motor control can compensate for limitations in operating range and the normal variability in speech movements to produce perceptually acceptable speech, while individuals with some

motor impairment may lack the flexibility to manage excessive variability during development, or movements outside the operating range, thus producing inaccurate speech (Robin et al, 1997).

Operating range has implications for assessment. Robin et al report that under laboratory conditions, the operating range for speech appears to be approximately 10-25% of the maximal envelope. Thus, for speech produced under conditions of little demand, such a range may be adequate. However, when demands increase, particularly when the envelope is reduced, speakers may be more prone to breakdown (speech errors). Thus Robin et al's view fits in with a limited resources view of speech production in SLI. Where normal speakers would have sufficient flexibility to manage the inherent variability in producing speech under different conditions and in different contexts, speakers with a reduced envelope would only function well under conditions of low demand. As demands increase, the likelihood of speech breakdown would increase.

Developmental phonological disorders in children with SLI may therefore be the result of auditory perceptual, cognitive-linguistic or articulatory-motor deficits. Such deficits may not resolve, at least not fully, and may therefore still impact on speech production in adolescents with SLI. There are certainly strong grounds to believe that the motor deficits seen in SLI may contribute to speech production difficulties, which is one of the hypotheses of this study.

2.4.3 Consequences of Developmental Speech Disorders

One of the reasons it is important to study speech disorders, is that speech sound disorders can have long-lasting consequences on a child's psychosocial adjustment, educational achievement, and eventual vocational choices that have been well-documented (Dodd, 1995b; Gierut, 1998; Shriberg, Flipsen, Kwiatkowski & McSweeny, 2003). From a psychosocial perspective, persistent misarticulations could have a negative impact on a speaker's self-concept, socialization and vocation. Unintelligible speech also has consequences for pragmatic needs in language acquisition. More recently, research has focused on the potential risk that

phonological processing deficits pose for reading, spelling and learning disability, and other areas of verbal learning (e.g. Bird, Bishop & Freeman, 1995).

Some contradictory findings are reported regarding the relationship between speech problems and literacy development, but contradictions appear to relate to methodological differences regarding the definition and identification of speech disorders, as well as outcome measures. The heterogeneity of speech disorders also led to contradictions, as some underlying causes for speech disorders are more closely linked to literacy development than others.

There appears to be substantive evidence that at least some children with speech disorders later have academic difficulties. Factors which are likely to increase the likelihood of academic difficulties in children with development phonological disorders include: the nature of the phonological errors, particularly errors involving sequencing (metathesis and assimilation) rather than segmental phonological errors such as substitutions and omissions (Catts 1993); the use of non-developmental phonological processes (Dodd, Gillon, Oerlemans, Russel, Syrmis & Wilson, 1995; Leitão & Fletcher, 2004); the presence of phonological disorder, as opposed to articulation disorder (Dodd et al, 1995) and the presence of severe expressive phonological impairments at the time of starting school (Bird, Bishop & Freeman, 1995). Specifically, it is thought that children must first be able to use the phonology of their language before they can consciously reflect on the phonological system, and that perception and production are prerequisites for the development of metaphonology (Swank & Larrivee, 1998). Similarly, Stackhouse (2000) proposed that the children who go on to have literacy difficulties have pervasive speech processing problems, affecting both the speech and language domains. Thus some children with speech disorders are at risk for spelling (Clarke-Klein & Hodson, 1995) and reading (Snowling, Bishop & Stothard, 2000) difficulties.

Children with SLI, who also have phonological impairments, may therefore be more at-risk for academic difficulties, than children without phonological deficits. Should certain types of phonological impairment in preschool be correlated to later literacy difficulties, children with SLI and DPD would be at risk for literacy

development not only because they have SLI (as will be discussed in Chapter 3), but also because they have DPD. Whether these two factors act as additive risk factors remains to be seen. However, if that is the case, children with SLI and DPD may be more likely to fall in the subgroup of persistent SLI, than children with SLI without phonological deficits.

2.5 Speech Errors

Lexical access has largely been studied through speech errors[5], either in non-impaired populations, or in aphasic populations. Sound errors are defined as utterances which deviate from the speaker's intention in the placement or identity of one or more phonological segments, but do not include morpheme errors (Meyer, 1992). However, when morphemes consist of a single phoneme (such as /s/ indicating plural form or third person singular agreement) it may be hard to differentiate between sound errors and morpheme errors. Such ambiguity in classification of errors has substantial implications for research on use of morphemes, particularly in preschoolers where sound errors are common.

The development of lexicalization theories has largely depended on the study of speech errors in unimpaired populations as well as aphasic populations. However, such a methodology can be criticized. Some studies have based their conclusions on speech errors which occurred during natural conversation in non-laboratory settings. Since this method relies on the ability of listeners to detect errors, it may not be entirely accurate (Meyer, 1992). Furthermore, speech is relatively error-free (Field, 2004), making it difficult to obtain sufficient data. Finally, many errors are ambiguous as they can be classified in more than one way (Meyer, 1992).

Nonetheless, speech error analysis remains a popular method of studying lexicalisation. The very fact that sound errors occur, shows that word forms are assembled out of smaller units, rather than being retrieved from the mental lexicon as single entities (Meyer, 1992), while evidence from assemblage slips of the tongue

[5] Such speech errors in normal speakers are usually referred to as "slips of the tongue", and refer to speech errors which provide insight into the storage and retrieval of lexical items, as well as the assembling of speech (Field, 2004).

indicate that the syllable is an important unit of planning (Field, 2004). More recently, the trend has been towards laboratory-induced speech errors, by eliciting words under varying conditions of linguistic and phonological complexity. For example, tongue twisters may be used to induce errors (Wilshire, 1999). This technique has also been criticized, as normal planning processes may be altered, and articulation may be more difficult than in spontaneous speech (Meyer, 1992). However, in a study such as the current one, where interactions among linguistic factors and phonological factors were being investigated, it was felt to be more appropriate to induce errors experimentally, where linguistic and memory factors could be manipulated.

Since this study is focused on speech sound errors in SLI, semantic errors will not be discussed. Phonological error types will be described, followed by a brief discussion of the constraints that appear to apply to errors.

Contextual errors account for 70% or more of errors collected from nonaphasic speakers (Goldman, Schwartz & Wilshire, 2001), and include: anticipations which involve replacement of a word or sound by one that was intended to occur later in the utterance; perseverations, when the replacing sound or word is one previously uttered; and exchanges, where two words or sounds change place. Errors that are phonologically close to targets suggest that an individual is able to activate the appropriate lemma, but has problems at lexeme level (Hanley & Kay, 1997).

Speech errors are not random, but are constrained by speech production processes (Meijer, 1997). Linguistic factors impact on ease or automaticity with which words are produced (Gordon, 2002): including semantic factors such as frequency, familiarity, imageability, and concreteness; syntactic factors such as grammatical class and morphological function; and structural factors such as level of stress, syllabic position and markedness.

The most widely cited observation about speech errors is obedience to phonotactic constraints. Sublexical substitutions obey phonetic rules, with the result that sound sequences that are not permissible in the language are not produced (Nadeau, 2001). Segmental errors also respect category distinction (Shattuck-

Hufnagel, 1992): consonants replace consonants and vowels replace vowels. Syllable onsets interact with syllable onsets and rhymes with rhymes. Thus target characteristics and well-formedness of output are retained. Word substitution errors have been shown to retain the length and overall stress pattern of the target. There are word position constraints, with a predominance of word-onset errors; as well as a syllabic constraint, which limits the range of allowable movements (Meijer, 1997). The phonetic well-formedness of errors would suggest that they occur during the creation of a phonological representation, rather than during phonetic encoding or articulation (Meyer, 1992). In studying speech errors in the SLI population it would therefore be important to establish if errors obeyed phonotactic constraints.

A lexical effect or word bias reflects that phonological errors tend to form real words more often than would be expected by chance. The lexical effect is thought to provide support for the concept of a postlexical editor, where errors resulting in nonwords are more likely to be detected (Levelt, 1992; Gagnon, Schwartz, Martin, Dell & Saffran, 1997). Gagnon et al proposed that it is when the postlexical editor is disrupted, that neologisms[6] occur more often than formal paraphasias[7]. Most word substitution errors also tend to belong to same grammatical class as targets. Implications for the current study are that speech errors would have to be analysed to determine whether they resulted in real words or nonwords.

There is also a frequency bias, where words and syllables which occur more frequently in the language are retrieved more rapidly (Gagnon et al, 1997). Frequent words have been found to be accurately produced more often than infrequent words, while Levelt & Wheeldon (1994, in Gordon, 2002) found an effect of syllable frequency, independent of lexeme frequency on picture naming latencies, and proposed that many overlearned syllables are retrieved directly, as gestural scores from a mental syllabary.

A length effect has been reported, where the length of a targeted word has been found to influence the susceptibility of words to error production for normal subjects

[6] A neologism involves the creation of a nonword by a (usually aphasic) speaker.
[7] A formal paraphasia involves the substitution of one word for another, based on the phonological similarity of the words.

(Levelt & Wheeldon, 1994). It is thought that opportunity for error increases with longer words, and longer words also tend to be less frequent. In the current study it would therefore be important to consider the length effect in deriving an assessment battery.

In adults with acquired neurogenic disorders, imageability of words to be repeated has been shown to have an effect on repetition accuracy (Hanley & Kay, 1997; Hanley, Kay & Edwards, 2002), i.e. some adults with neurogenic disorders rely heavily on the activation of a word's meaning to aid auditory repetition. Individuals with SLI, who frequently have a limited lexicon, may not be able to rely on word meaning to aid repetition, which would render such tasks more difficult.

The linguistic deficits of individuals with SLI could therefore interact with and impact on the selection of lemmas and lexemes. Processing limitations seen in children with SLI could impact on all stages of lexicalization, with control processes such as the postlexical editor possibly being particularly susceptible to processing limitations.

Processing limitations could impact a on number of stages during the speech production process. Leonard (1998) proposed that slower processing would affect phonological encoding. Longer and more grammatically complex sentences would require retrieval of a greater number of lemmas, morphemes and segments. Complex morphological, metrical or segmental forms will also require more time to be generated, placing time pressure on other phonological encoding processes. Leonard suggested that the interaction among metrical, prosodic and morphological information is likely to place severe demands on children with SLI. Temporal demands for these processes may exceed the processing speed of children with SLI, thus processes involved in phonological encoding might be left incomplete or lead to inaccurate encoding.

2.6 Methodological Considerations

Based on the preceding discussion, the following factors were taken into consideration in designing the current study:

- The impact of linguistic variables on motor tasks should be controlled as far as possible. Consequently discourse tasks or tasks requiring complex syntactic or semantic processing are not appropriate in the speech assessment.
- A speech assessment battery has to be sensitive to residual errors not readily evident in traditional speech assessments or spontaneous speech samples.
- Automaticity of speech production in this population must to be assessed. Any assessment instrument should therefore consider efficiency and speed of responses.
- Some speech sound deficits may be related to phonological awareness abilities, thus the study should incorporate a phonological awareness assessment.
- To facilitate the use of current classification systems for paediatric speech disorder, the assessment should allow for the description of speech symptoms as well as an investigation into etiological factors. Tongue twisters were seen as a useful tool to induce speech errors in speakers without markedly overt speech deficits.
- Speech error data provided useful guidelines regarding the selection of stimuli to induce errors, particularly with regard to manipulating the length and familiarity of stimuli.
- Models of speech production provided a useful framework for the analysis of speech errors, which will be discussed in more detail in Chapter 5.

2.7 Summary and Conclusions

Motor speech production within an information processing framework has implications for all aspects of verbal communication. Strand and McCauley (1999) suggest that a set of assumptions arise from Caruso and Strand's (1999) model (and by implication, van der Merwe's model): 1) The interaction of sensorimotor processes are fundamental to articulatory performance and must be considered in addition to the more global interactions among cognitive, linguistic and motor processing. 2) Resource allocation impacts the child's ability to manage speech motor control processes in order to produce speech, especially as other processing demands,

such as linguistic complexity, increase. 3) As speech is acquired, there is progressive movement from controlled to automatic motor processing, with further consequences for resource allocation.

The implications of these assumptions are that speech production is more resource-demanding in children than in adults, and that children with compromised linguistic systems may find tasks involving speech more resource-intensive. In view of the redundancy of the speech system and interactions with the linguistic system, an impaired linguistic system may increase the likelihood of speech errors, by drawing resources away from speech production; or an impaired speech system may be evident in linguistic breakdown, rather than overt speech errors.

The above discussion suggests that adolescents with SLI have vulnerable speech production systems, particularly at the levels of phonological and motor planning, because of their linguistic and motoric deficits, while the operation of the buffer during speech production may be compromised because of limited working memory ability. Adolescents with SLI are therefore thought to have a reduced operating range for speech, which may result in inconsistent residual errors, particularly when resource demands increase. Furthermore, because of the high comorbidity of SLI and DPD, many adolescents with SLI may have a history of DPD, suggesting that auditory-perceptual, cognitive-linguistic or articulatory-motor factors impacted on their speech production. These factors may not have resolved fully by adolescence and may therefore still influence speech production in this population. The current study has focused particularly on the motoric aspects of speech production in adolescents with SLI.

From the above discussion it is apparent that even unimpaired populations present with speech errors. It is the hypothesis of this study that in the SLI population the incidence of such errors is increased because of their linguistic, motoric and information processing deficits. These factors will be considered in Chapter 3 where the phenomenon of SLI will be discussed.

3 Specific Language Impairment

Specific language impairment (SLI) is one of the best-described and well-researched language disorders, yet at the same time is an elusive and poorly understood concept. Individuals with SLI make up a substantial proportion of the clinical caseload of Speech-language pathologists (SLPs), who consequently require a good understanding of the features associated with the disorder, including the speech characteristics of individuals with SLI. However, while the language abilities of children with SLI have been well-described, their speech production has received little attention in the past. Most research in SLI has also focused on preschool children or school-aged children with few studies investigating SLI in adolescents. The current study proposes that speech difficulties form an integral part of the disorder, and that such difficulties persist into adolescence.

In the sections below, SLI will be described in terms of its definition, its diagnostic criteria, linguistic and non-linguistic characteristics, and its heterogeneity. Thereafter explanations of SLI will be presented, with emphasis on processing limitations as an explanatory framework. The threshold effect will be presented as a possible explanation for speech deficits in adolescents with SLI. Finally, risk factors pertaining to SLI will be presented, with reference to those factors which also pertain to DPDs.

3.1 Definition of Specific Language Impairment (SLI)

For a disorder that has been studied extensively since the early 1980s, SLI is still not well-defined, and is diagnosed primarily by exclusion (e.g. Lahey & Edwards, 1995; Leonard, 1998). Children with SLI are healthy, and otherwise typically developing, yet present with unexpected and unexplained language difficulties (Tomblin, Smith & Zhang, 1997; Hammer, Tomblin, Zhang & Weiss, 2001), or as Leonard (1998, p.3) stated, these children "…show a significant limitation in language ability, yet the factors usually accompanying language learning problems – such as hearing impairment, low nonverbal intelligence test scores, and neurological damage – are not evident". The assumption is that these children have no physical or

sensory deficits, severe emotional disturbances, detrimental environmental factors, or brain damage (Kamhi, 1998).

The term *specific language impairment* has been used consistently only since the early 1980s, but this population has been studied for over a century (Leonard, 1998), with different "labels" having been used to describe the population at different times. Children with SLI have been referred to as *developmentally aphasic/ dysphasic, or language impaired/ disordered/ delayed/ disabled* (Kamhi, 1998; Leonard, 1998). Some of these terms, particularly the aphasic/dysphasic terms, have fallen into disuse, primarily because of their emphasis on neurological dysfunction. The term *language delay* is still used by clinicians, but is not strictly accurate, since the term *delay* implies that these children will eventually "catch up" (Kamhi, 1998), while for many individuals SLI is known to persist into adolescence and adulthood (Leonard, 1998).

Children with SLI need to meet a number of diagnostic criteria before they can be diagnosed as such for research purposes. In some instances where researchers have felt unable to meet the strict criteria, they have reverted to using the term *language impairment*, although it is clear from their participant description that they are (at least in part) discussing SLI (e.g. D.V.M. Bishop, S.J. Bishop, et al, 1999).

The current study has retained the use of the term s*pecific language impairment (SLI)*, because of the specificity of the selection criteria used to recruit participants. However, it is the view of this study that "specific" language impairment is not particularly specific. It is likely that children with SLI have a broader range of difficulties, including speech impairment and motor incoordination. In trying to make sense of SLI such broader difficulties cannot be ignored, not only because of their influence on language development, but because they may form an integral part of the phenotype of SLI.

3.2 Description of Specific Language Impairment (SLI)

SLI is one of the most commonly occurring developmental disorders. Prevalence rates may vary, depending on the criteria used in a particular study. The most widely accepted prevalence rate is approximately 7.4%, based on a large epidemiological

study (Tomblin, Records, et al, 1997)[8], rendering SLI one of the most common paediatric communication disorders treated by SLPs.

3.2.1 Diagnostic Criteria

Clinicians working in the field of child language disorders have little difficulty understanding the concept of SLI. Intuitively they know that these children exist, yet defining this population is much more difficult. Kamhi (1998) suggested that current definitions of language disorder certainly describe the problem quite well, yet do not provide a criterion to determine when a language disorder exists. As a result there is much variability in the criteria used to diagnose SLI.

SLI is typically defined by a combination of inclusionary, exclusionary and discrepancy criteria.

Inclusionary Criterion*:* The most consistent inclusionary criterion is a clinical diagnosis of language disorder (Kamhi, 1998). More recently, it has been suggested that a basic processing deficit could be used to distinguish children with intrinsic language disorders from those whose language impairments are caused primarily by extrinsic environmental factors (e.g. Spitz, Tallal, Flax & Benasich, 1997; Kamhi, 1998). Measures used to diagnose such a processing deficit could include a test of nonword repetition (e.g. Gathercole, Willis, Baddeley & Emslie, 1994; Dollaghan & Campbell, 1998) and/or a test of temporal processing skills (Tallal, 1990). Performance on tests of nonword repetition and temporal processing are seen to be strong diagnostic indicators of SLI.

Exclusionary Criteria*:* The primary aim of the exclusionary criteria is to differentiate children with specific impairments from children whose language/learning impairments can be attributed to known facts. Typically, the following factors are excluded: Peripheral hearing loss; frank neurological

[8] Tomblin and colleagues used the following criteria: A performance IQ cutoff of 85, and standard exclusionary criteria. Language impairment was identified on the basis of five composite scores from a standardized test, such as the Test of Language Development-2-P (TOLD-2-P; Newcomer & Hammill, 1988), where the child obtains two or more composite scores -1.25 SD or more below the mean for his/her age (Tomblin, Records, et al, 1997). These criteria were judged to have good specificity and sensitivity (Leonard, 1998).

disabilities; emotional disturbance; mental retardation (developmental delay); and severe phonological disorders (Stark & Tallal, 1981a; Aram, Morris & Hall, 1993; Kamhi, 1998; Leonard, 1998). In some instances, researchers have also tried to exclude language deficits resulting from sociocultural or environmental factors (Kamhi, 1998; Leonard, 1998).

Discrepancy Criteria*:* As SLI is regarded as a language disorder in the absence of other impairments, discrepancy criteria are often used to identify a disparity between language and other non-impaired aspects of cognitive functioning (Aram, Morris & Hall, 1993). Typically, a discrepancy is required between a child's expected performance, (which can be defined by chronological age, grade level, mental age or nonverbal IQ), and actual language performance (Dunn, Flax, Sliwinski & Aram, 1996).

While the inclusionary and exclusionary criteria are clearly necessary for a diagnosis of SLI, and the discrepancy criteria seem to make logical sense, researchers and clinicians have found it difficult to establish consistent operational criteria. For example, the method by which discrepancy is determined differs between researchers and clinicians, as well as among researchers (Plante, 1998; Dunn, Flax, Sliwinski & Aram, 1996). In 1981, Stark and Tallal published an article which was regarded as the "gold standard" outlining selection criteria to identify children with SLI for research purposes. Most subsequent research studies in the area of SLI followed the principles they proposed, if not their exact procedures and tools. However, in recent years some of their basic assumptions have been challenged (e.g. Kamhi, 1998; Plante, 1998; Dunn, Flax, Sliwinski & Aram, 1996), and other selection criteria have been proposed. Since the majority of research studies reviewed in these chapters have followed the Stark and Tallal (1981a) principles, this issue will not be discussed further here, but will be raised again in the discussion regarding methodological considerations for this study (see Chapter 5).

SLI will now be described in terms of its linguistic and nonlinguistic characteristics, which are summarised in Figure 3-1 below.

Although studies may have used different operational criteria to identify participants with SLI, the characteristics described below have been found repeatedly in a number of different studies, and can therefore be regarded as an accurate description of the population as a whole. However, as will be pointed out in the section on the heterogeneity of the SLI population, not all characteristics will apply to all children with SLI.

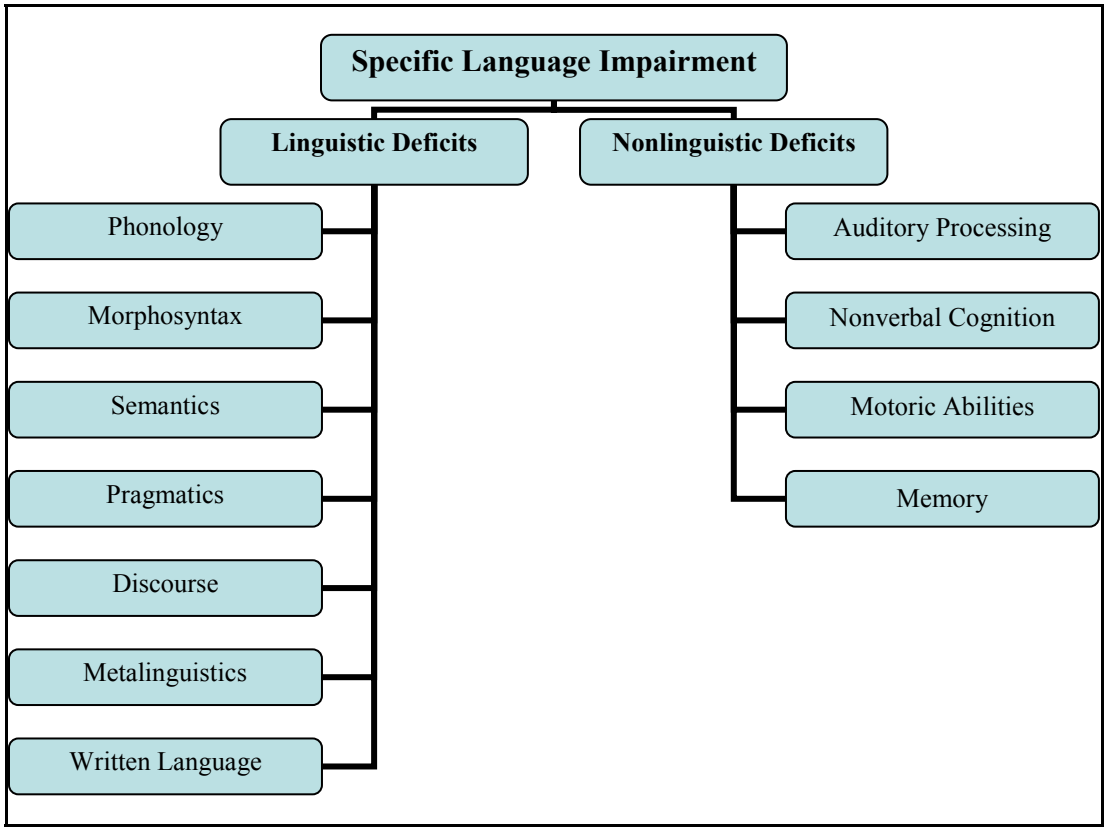

Figure 3-1: Areas of deficit in individuals with specific language impairment (SLI).

3.2.2 Linguistic Characteristics

This section will describe the morphosyntactic, semantic, pragmatic, discourse, metalinguistic and written language characteristics of children with SLI. However, the majority of studies in the area of SLI have focused on describing the language characteristics of children between the ages of 4 and 12 years of age (Heilmann, 2004 in Miller & Fletcher, 2005). Descriptions of the speech abilities of these children are limited, and little attention has been directed to SLI in adolescence. Phonological

development in children with SLI, which is often impaired, will be discussed in Chapter 4.

Deficits in the area of morphosyntax are regarded as a defining feature of SLI, and have been well-described (e.g. Leonard, McGregor & Allen, 1992; Clarke & Leonard, 1996; Craig, 1996; Kamhi, 1996, 1998; Leonard, Eyer, Bedore, & Grela, 1997; Leonard, 1998; Rice, Haney & Wexler, 1998; van der Lely & Christian, 2000; Evans, 2001). Children with SLI acquire the major grammatical categories and syntactic ordering rules in the same order as typically developing children, but this development is markedly protracted (Johnston, 1988). As a result there is an atypical association between syntactic and morphological development, as morphemes are only acquired at later stages with more complex sentence structure than typically developing peers (Kamhi, 1996), resulting in utterances that are unlike any of those produced by non-impaired children.

Semantics may also be impaired, with vocabulary deficits regarded as a common feature of SLI (Clarke & Leonard, 1996; Leonard, 1998; Gray, Plante, Vance & Henrichsen, 1999; Evans, 2001). First words are often acquired later, while studies have documented significantly poorer word learning than typically developing peers under a number of experimental conditions (Oetting, Rice & Swank, 1995; Ellis Weismer & Hesketh, 1996; Gray, Plante, Vance & Henrichsen, 1999; Gray, 2004). Semantic relatedness has also been implicated (Craig, 1996). Both lexical processing (word recognition) and word retrieval are problematic (Marinellie & Johnson, 2002; Montgomery, 2002a), with naming errors being common (Lahey & Edwards, 1999; McGregor, Newman, Reilly & Capone, 2002).

Pragmatic deficits are not a defining feature of SLI, but do appear to occur in a subset of children (Craig & Evans, 1989, 1993; Craig & Washington, 1993; Craig, 1993, 1996; Conti-Ramsden, Crutchley & Botting, 1997; Evans, 2001). Most children with SLI are purposeful and responsive conversationalists (Johnston, 1988), whose communicative failures may be primarily due to impaired morphosyntax or semantics. Nonetheless, from a pragmatic perspective, children with SLI are ineffective communicators (Craig, 1996). Sometimes pragmatics may be problem in

its own right (Leonard, 1998), and Craig (1996) reported that there may be a subset of children with SLI who experience more interactional difficulties than predicted by their linguistic form deficits.

In view of their many other linguistic deficits, it is not surprising that children with SLI struggle with discourse. Narrative discourse in SLI has been investigated extensively (Kamhi, 1996), and found to be significantly impaired with regard to topic maintenance, event sequencing, explicitness (including referencing), conjunctive cohesion and fluency (Miranda, McCabe & Bliss, 1998). Children with SLI are also less able to use language features associated with written language in oral narratives, than typically developing peers (Kaderavek & Sulzby, 2000).

A variety of metalinguistic abilities may be impaired in children with SLI. Definitional skill is often poor (Marinellie & Johnson, 2002). Phonological awareness skills which are prerequisites to early reading, are influenced significantly by general oral language development (Cooper, Roth, & Spencer, 2002), and are thus often impaired in children with SLI. There is ample evidence that segmentation, discrimination and identification of speech sounds is impaired in children with SLI (D.V.M. Bishop, S.J. Bishop et al, 1999).

The oral language deficits present in the SLI population often affects the acquisition of written language (Gillam & Johnston, 1992; Gillam & Carlile, 1997; Leonard, 1998; Flax et al, 2003), placing these children at risk academically and economically (Tomblin, Smith & Zhang, 1997). Children with deficits in the areas of vocabulary and/or morphosyntax, as well as phonology, are most likely to develop reading problems (Bishop & Adams, 1990; Lewis & Freebairn, 1992; Catts, 1993). There is strong support for a relationship between language impairment and subsequent reading problems, but it is clear that not all language impaired individuals develop reading problems (Flax et al, 2003).

3.2.3 Nonlinguistic Characteristics

It has long been acknowledged that despite the absence of generalized cognitive deficits, various perceptual, cognitive and motoric limitations are associated with SLI

(e.g. Rutter, Mawhood & Howlin, 1992; Ellis Weismer & Hesketh, 1996). In recent years there has been mounting evidence that children with SLI experience a range of deficits outside of the syntactic system, including auditory perceptual deficits (particularly involving temporal processing), memory deficits and general processing capacity limitations (Ellis Weismer & Hesketh, 1996; Frazier Norbury, Bishop & Briscoe, 2002).

Auditory processing deficits: The rapid processing of temporal information has been implicated as an explanation for SLI by Tallal and colleagues (e.g. Tallal, 1990). Some support for this view was provided by Joanisse and Seidenberg (2003), who used a connectionist model of sentence processing to demonstrate how impaired speech perception could produce grammatical deficits in SLI; and Criddle and Durkin (2001) who reported that children with SLI were less able to form fully specified phonological representations of morphemes under conditions of low perceptual salience. However, recent studies have indicated that auditory processing deficits are neither necessary nor sufficient to cause language impairment in children, and that performance on measures of auditory temporal processing may reflect the test method, attention, failure to adapt to task demands, or slow learning of novel tasks (Bishop, Carlyon, Deeks & Bishop, 1999), or just general limitations in processing capacity (Leonard, 1998; Criddle & Durkin, 2001).

Nonverbal Cognition: Individuals with SLI often have impaired nonverbal cognitive abilities, affecting anticipatory imaging tasks, such as spatial-rotation tasks; as well as analogical reasoning skills, symbolic play, hierarchical planning, hypothesis generation and mental imagery (Leonard, 1987, 1998; Swisher, Plante & Lowell, 1994; Kamhi, 1996). Such deficits could point to an underlying cognitive processing inefficiency (Kamhi, 1996). It would appear paradoxical that children with such marked nonverbal cognitive deficits still score within the average range or above on nonverbal IQ tests. Leonard (1998) proposed that this occurs, partly because many of the tasks on nonverbal IQ tests assess aspects of visual perception, which is an area of relative strength for children with SLI. A second possible explanation relates to the

impact of language intervention, which has been shown to increase scores on standardized tests (Leonard, 1998).

Motoric Abilities: Perceptual and motor development has also been implicated in SLI. For example, Tallal (1985 in Rutter, Mawhood & Howlin, 1992) reported perceptuomotor impairments and difficulties with temporal sequencing; Bishop and Edmundson (1987) showed links between motor and language development; and Stark, Mellitis and Tallal (1983 in Rutter et al, 1992) found that the degree of perceptuomotor impairment predicted language outcome. In a series of MRI studies, Plante and colleagues (Swisher & Plante, 1993) found that children with SLI have atypical brain development in areas beyond those classically associated with language skills.

Genetic studies have provided further support for the comorbidity of motor and communication deficits. Bishop (2002b) reported on a twin study, which found that the genes which put a child at risk for communication problems also produce motor deficits and that the association is most pronounced when speech production is affected. Although her study refers to SLI, it also included children with speech problems only, rendering the diagnosis of SLI questionable.

In an article reviewing literature on SLI and motor abilities, Hill (2001) concluded that substantial comorbidity exists between SLI and poor motor skill, suggesting that SLI is not a neurodevelopmental disorder specific to language, but that motor incoordination is one of a broader range of difficulties found in this population. Her finding provides further support for one of the major arguments of this study, that studies which exclude children with SLI with marked speech disorder, for fear of including children with underlying motor deficits, are excluding precisely the type of children who are typical of the SLI population.

Since the early 1980s, it has been clear that many children with SLI have manual-motor deficits. Stark and Tallal (1981b), found that children with SLI have poorer performance on tasks requiring rapid, repetitive or sequential actions, than controls. Tallal et al (1989, in Redmond & Rice, 1998) reported that a language-impaired group could be differentiated from a control group 93% of the time based on

either direct estimates of language skills, or interpretations of neurodevelopmental integrity, such as clumsiness. In their comparison of the performance of children with SLI on a number of different nonverbal IQ tests, Swisher, Plante and Lowell (1994) found robust effect sizes for manual-sequential praxis, suggesting that this is a common area of deficit in this group.

Using stringent search criteria, Hill (2001) identified twenty-eight papers assessing limb coordination in children with a specific neurodevelopmental disorder of language (SLI). She concluded that fine and gross motor deficits, as well as poor motor skills are characteristic of children with SLI. The studies she reviewed yielded the following trends which are relevant to the current study. Firstly, the co-occurrence of Developmental Coordination Disorder (DCD)[9] and SLI ranged from 40% to 90%, well above the estimated 6% prevalence of DCD. Secondly, there were marked impairments in time taken on fine motor tasks in children with SLI compared to normally developing peers although no impairment was found with regard to performance accuracy on fine motor tasks. Thirdly, children with SLI resembled both children with DCD, and younger, normally developing peers on limb praxis tasks. Fourthly, Dewey et al (1988, in Hill, 2001) reported that children with SLI had an unimpaired ability to learn individual movements in a sequence, and suggested that where a deficit exists, it may be caused by the planning, integration and/or execution of a combination of postures into a sequence. Such a finding has important implications for speech production, which requires the rapid combination and sequencing of a number of movements. Finally, with regard to subgroups of SLI, children with expressive language deficits, and those with inconsistent phonological errors were most likely to present with motor impairments. These findings lend support for the idea that different subgroups of SLI have different underlying etiologies.

[9] Developmental Coordination Disorder (DCD) is a neurodevelopmental disorder defined as significant movement difficulties out of proportion with general development, and in the absence of identifiable neurological or medical conditions (Sugden & Wright, 1998; Hill, 2001). Its prevalence is estimated at 6% (APA, 1996).

It is of interest to note that Developmental Coordination Disorder (DCD) is often associated with phonological disorder, expressive language disorder and mixed receptive-expressive language disorder (Sugden & Wright, 1998), suggesting that coordination is implicated in disorders affecting speech and language output. This finding is not unexpected as speech requires the most refined fine motor control in the body (Bahr, 2001).

Coordination for speech requires appropriate muscle selection and tension, and precise timing and sequencing of articulatory dynamics, and is a hallmark of normal sensorimotor function that characterizes eye, limb and speech movement (Caruso & Strand, 1999). Caruso and Strand suggest that coordination within the speech system should be viewed as one within a system that governs the body as a whole. The implication is that if motor coordination in the rest of the body is affected, coordination for speech could also be impaired. Similarly, Crary (1993) proposed a motolinguistic model of cortical motor speech disorders. He suggested that overlapping motor and speech-language functions exist within the left hemisphere areas traditionally associated with language. Therefore, although motor and speech dysfunctions could occur independently, the dysfunctions may co-occur, in which case the dysfunctions would be inter-related and not just co-occurring. He also proposed that there are various steps or levels in information processing which could pertain to both motor and speech-language functions. As a result, when motor and speech deficits co-occur, the pattern of dysfunction will be similar. An important facet of Crary's model, is the idea of a continuum, rather than discrete categories, suggesting that motor speech disorders could take a very mild form.

As Paul (2000) pointed out, the fact that gross motor skills have some role in predicting later language outcome provides further information regarding the source of language delay, and provides support for Bishop and Edmundson's (1987) argument that SLI reflects a general neurodevelopmental lag affecting a variety of areas of development, including motor skills, rather than being a specific deficit.

From the above discussion, it appears that the condition of SLI is not just specific to language, lending further support to the hypothesis of this study, that speech

difficulties may also be characteristic of this disorder. Thus far, the majority of studies investigating motor skills in children with SLI have investigated gross motor, perceptuomotor or manual skills, with little attention directed to oral motor control, which is one of the areas included in the current study.

3.2.4 One Disorder or Many Disorders? The Heterogeneity of SLI

As can be expected of a group defined by what they are **not**, rather than by what they **are**, the SLI population is heterogeneous, and individuals with SLI may show markedly different language characteristics from one another (van der Lely & Stollwerck, 1996). At any one age, a group of children with SLI may have differential impairment with regard to expressive versus receptive impairment, or differential impairment of phonology, morphosyntax, semantics, and pragmatics.

SLI is also heterogeneous across ages. Some children's language impairments resolve (resolving SLI), while others persist (persistent SLI); for some children SLI is only an oral language disorder, while for others the disorder later becomes a language-learning difficulty. The only universal feature appears to be generally slow and poor language learning (Leonard, 1998).

The heterogeneity of SLI has substantial implications for participant selection in research studies. The reliance on exclusionary criteria results in the identification of a heterogeneous group with varying degrees of expressive and receptive language problems, varying profiles of strengths and weaknesses, and marked differences in other areas of weakness (Stark & Tallal, 1981a; Leonard, 1987, 1998; Sloan, 1992; Aram, Morris & Hall, 1993; Kamhi, 1998; van der Lely & Christian, 2000). As a result one has to be careful in interpreting research results, as findings may not always apply to all children with SLI.

Several authors (Tomblin, Freese & Records, 1992; Rice, 1996; Rice & Wexler, 1996; Bishop, 2002a) have emphasized the need to specify a reliable phenotype or description of inclusionary criteria for SLI. For example, Rice (2004, p.208) proposed that current attention should focus on the need "…for greater precision in the language phenotype, for improved accuracy in the identification of affected

children, and more precise description of the dimensions of affectedness". An accurate description of the nature of the language and language-related strengths and weaknesses of children with SLI will eliminate the need to use nonverbal IQ or discrepancy formulae as criteria for group membership (Kamhi, 1998) thus reducing errors in detecting affected individuals; and to develop more accurate methods of determining genetic influence (Rice, Haney & Wexler, 1998).

However, it is quite likely that more than one phenotype of SLI exists. The validity of SLI as a single construct with a single etiology has been questioned (Leonard, 1987, 1991, 1998; Aram, 1991; Miller, 1987 in Fletcher, 1992; Aram, Morris & Hall, 1993; Gathercole & Baddeley, 1994; Lahey & Edwards, 1995). Even the original Stark and Tallal (1981) article suggested that "specific language deficit" is a misleading term, as the group is heterogeneous, showing different patterns of deficit in speech and language skills. Ten years later Aram (1991) also proposed that the category of SLI is composed of a number of subgroups whose overlapping and defining feature is that of language impairment, and that no single cause would explain more than a subset of the overall group of children with SLI. Trying to specify *the* phenotype for SLI may therefore be an impossible task.

While some attempts have been made to identify subgroups within the SLI population no single typology has been widely accepted. A disorder such as aphasia can be described using a taxonomy of syndromes developed over decades of research, but research on SLI has struggled to develop distinctions beyond an expressive-only versus a mixed receptive-expressive group (Garman, James & Stojanovik, 2005). Thus far, there is little consistency across studies regarding the subgroups investigated or the criteria used to identify such groups.

Subtypes have been described in terms of differences with regard to receptive and expressive language, as well as the variable impairment of phonology, morphology, syntax, semantics and pragmatics (Aram, 1991). Initially research focused on developing taxonomies for SLI (e.g. Aram & Nation, 1975; Wilson & Risucci, 1986; Wolfus, Moscovitch & Kinsbourne, 1980; Rapin & Allen, 1988). More recently researchers have aimed to describe specific subtypes of SLI. Some

subtypes that have been described include Grammatical SLI (G-SLI) (van der Lely & Christian, 2000); expressive SLI (Whitehurst et al, 1991; Evans & MacWhinney, 1999); receptive-expressive SLI (Evans & MacWhinney, 1999); semantic-pragmatic SLI (Bishop & Adams, 1989); resolving SLI (Bishop & Edmundsen, 1987); persistent SLI (Stothard et al, 1998; Catts et al, 2002; Bishop, Price, Dale & Plomin, 2003); SLI with pragmatic deficits (Craig, 1996); or individuals with co-occurring articulatory and non-verbal deficits (Vargha-Khadem et al, 1995 in van der Lely & Christian, 2000).

The current study focused on one particular subgroup of SLI. Since adolescents with SLI form the focus of the study, participants can be regarded as representative of persistent SLI. Results of this study may therefore not be applicable to the larger SLI population.

It has long been recognized that there is likely to be a subtype of SLI characterized by speech production difficulties. For example, Aram and Nation (1975) identified a nonspecific formulation-repetition disorder in addition to a speech-programming disorder; Wolfus, Moscovitch and Kinsbourne (1980) mentioned syllable production problems; Rapin and Allen (1983, 1988) identified a phonologic production/verbal dyspraxia disorder and a speech planning/programming disorder; and van Daal, Verhoeven and van Balkom (2004) isolated a speech production subgroup. These subtypes have focused primarily on the motoric aspects of speech production, but do suggest that speech production abilities could differentiate among subtypes of SLI.

With the exception of studies involving the KE family[10] in the UK, there has not been a concerted effort to investigate speech production as a differentiating feature of SLI subtypes. Even with these studies there is some question whether the KE family reflects a unique gene mutation, or in fact that all members of this family meet the criteria for SLI, reducing the likelihood that characteristics found in this family would apply to other people with SLI.

[10] The KE family has been described extensively (e.g. Gopnik & Crago, 1991; Ullman & Gopnik, 1999). Over half the members of this British family present with severe speech and language disorders.

The heterogeneity of the SLI population has implications for the validity of the field. Leonard (1982, p. 306) suggested that: "Given the heterogeneity of the language impaired population, the assumption that language-impaired children can be studied as a group is quite risky, and no doubt most studies have been subject to a wide intersubject variability." More recently, Garman, James and Stojanovik (2005) have suggested that the high variance in populations such as SLI, coupled by small sample sizes in many studies, pose a serious threat to the validity of the field. At this point, the term SLI can be seen as a useful superordinate term (Kamhi, 1998) to describe children with developmental language disorders, who do not fit into other major etiological categories. However, individuals within this category may differ markedly from each other, depending on the variables evaluated.

A number of explanations have been proposed for the language deficits typical of SLI. In the section below, these explanations are presented.

3.3 Explanations of SLI

There are currently three prevailing views regarding the nature of SLI which are reflected in Figure 3-1 below. The disorder can be viewed as 1) a disorder of language only; or 2) a language disorder related to specific processing deficits, such as memory deficits; or 3) a language disorder related to processing limitations. The current study has adopted this third view as the most likely explanation of SLI, but 4) emphasizes the role of motoric limitations and speech production difficulties in contributing to processing limitations.

Figure 3.2 below provides a representation of these four viewpoints, where viewpoint 1 (orange) reflects only a language disorder, viewpoint 2 (blue) reflects a language disorder associated with a specific memory processing deficit and viewpoint 3 (green) reflects a language disorder related to processing limitations, to which a memory deficit may contribute (hence the dashed line). The viewpoint adopted in the current study is reflected by the purple block, indicating that motoric and speech production deficits contribute to the processing limitations which are manifested as

language deficits. Each of these four viewpoints will now be discussed in more detail.

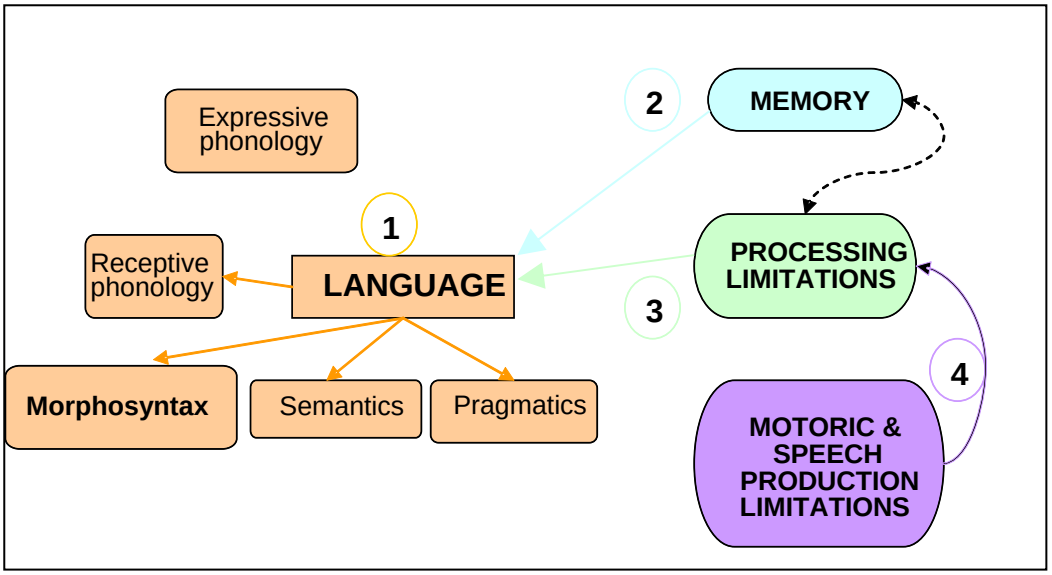

Figure 3-2: Four explanations of SLI.

3.3.1 Language Disorder Only

Theories of SLI can usually be divided into competence-based versus performance-based models (Ellis Weismer & Evans, 2002). Competence-based models of SLI suggest that the disorder purely reflects a lack of linguistic competence, because innate linguistic structures are absent or impaired (Evans, 2001): for example, a lack of knowledge of grammatical rules. Performance-based models (which will be discussed below) reflect difficulties with the real-time processing of language.

A modular view of language suggests that SLI reflects impairment of specific language modules. For example, van der Lely and colleagues identified a specific subtype of Grammatical SLI, which they have suggested may have an underlying domain-specific and modular language deficit resulting in severe impairment of inflectional morphology, without nonlinguistic deficits (van der Lely & Stollwerck, 1996; van der Lely & Christian, 2000). Grammatical SLI specifically excludes children with severe articulatory or phonological disorders. However, this group

appears to represent a relatively small subset of children with SLI. Van der Lely and Stollwerck reported that in a sample of 61 children with SLI, only 12 (19.6%) met the criteria for Grammatical SLI. This subtype of SLI is not widely accepted and van der Lely has been heavily criticised for the method used in her studies (e.g. Gathercole & Baddeley, 1995).

Other authors have proposed that specific linguistic mechanisms underlie SLI. For example, the Extended Optional Infinitive (EOI) theory was developed specifically to account for the morphosyntactic deficits seen in SLI (Rice, Haney & Wexler, 1998). This theory proposed that a very selective grammatical deficit operates for protracted period in SLI, namely that young children with SLI take longer than other children to mark grammatical tense in root clauses. Rice et al have demonstrated that surface phonological properties of the affected morphemes do not account for patterns of surface dropping (Oetting & Rice, 1993; Rice & Oetting, 1993) and cross-linguistic studies have suggested that rather than surface properties, it is the underlying grammatical representations that control where tense must be marked, that are affected (Rice et al, 1998). Rice et al propose that an EOI deficit would account for the serious morphological deficits noted in the preschool and early school age population, but acknowledge that it is unlikely to be the only deficit operating in children with SLI.

In a number of studies involving the KE family, Gopnik has proposed that specific linguistic deficits underlie SLI (e.g. Ullman & Gopnik, 1999). However, there is increasing evidence that the KE family represent a unique genetic mutation, and that their profile cannot necessarily be generalized to other individuals with SLI.

Language-only explanations of SLI have focused primarily on the characteristic morphosyntactic deficits evident in this disorder. Such theories would acknowledge the concurrent deficits in semantics, pragmatics and receptive phonology. Thus, while expressive phonology impairments may serve as an exclusionary criterion for SLI, it is widely acknowledged that children with SLI have impairments of phonological awareness or phonological representation (Edwards & Lahey, 1998). As seen in Figure 3-2, a language-only account would include most language

domains, but expressive phonology is usually seen as a separate entity which is excluded in explanations of SLI.

The heterogeneity of the SLI population, and the range of linguistic and nonlinguistic deficits evidenced in this population, as discussed earlier in this chapter, do not support theories proposing a language-only deficit in all children with SLI, although these theories may assist in accounting for the morphosyntactic deficits seen in SLI. Performance-based accounts have been proposed as a more likely explanation of SLI.

3.3.2 Specific Processing Deficits: Memory

There is much evidence to show that SLI is often associated with specific limitations in phonological working memory, the memory involved in processing information that is phonologically coded (Kamhi, 1998). It should be noted that for a number of years a deficit of rapid temporal processing was also proposed as an explanation of SLI involving a specific processing deficit. However, a number of studies have concluded that the rapid temporal processing deficits seen in individuals with SLI are more readily explained by general processing limitations, than a temporal processing deficit per se (Leonard, 1998; Hanson & Montgomery, 2002), while a study by Bishop, Carlyon, Deeks and Bishop (1999) demonstrated that a rapid auditory temporal processing deficit was neither necessary nor sufficient for SLI. While rapid temporal processing deficits may certainly contribute to the disorder, such deficits have therefore not been discussed as an explanation for SLI.

In the section below models of working memory pertaining to SLI will be discussed, followed by a description of the hypothesized impact of memory deficits on children with SLI.

Models of Working Memory

Studies by Baddeley, Gathercole and colleagues[11] have been influential in describing the memory deficits of children with SLI, while the work of Daneman,

[11] See Gathercole, Willis and Baddeley (1991); Gathercole, Willis, Emslie and Baddeley (1992); Gathercole and Baddeley (1994); Gathercole (1995); Adams and Gathercole (1995, 2000); Gathercole,

Carpenter and colleagues has also been used[12]. The two models are seen as being compatible, with the Daneman and Carpenter model fitting into the central executive component of Baddeley's model.

Gathercole and Baddeley's work (based on Baddeley's [1986] model) conceptualises working memory as a multi-component, resource-limited system, which is involved in general cognitive functioning. Baddeley's model consists of four components: the central executive and its two slave systems, the phonological loop and the visuospatial sketchpad, as well as an episodic buffer. A deficit in either the phonological loop or the central executive (or both) could explain the linguistic deficits seen in SLI.

Central Executive: The limited capacity central executive operates across modalities. Its function is to control or regulate information flow into working memory, interface and retrieval from other memory systems, and the allocation of resources for the processing and storage of information. Processing takes precedence over storage (Goolkasian & Foos, 2002), with the result that as processing demands increase storage is reduced.

Similarly, the Daneman and Carpenter model is a resource-sharing model (roughly equivalent to the language processing component of Baddeley's central executive), which has the view that storage and processing share a limited pool of resources (Montgomery, 2000b). Thus, if demands on memory exceed resources, there is a trade-off between storage and processing, with more resources allocated to processing than storage. In their model, linguistic deficits would indicate that more resources are allocated to processing of linguistic information, with insufficient resources available for storage of information, resulting in a functionally smaller temporary storage capacity (Goolkasian & Foos, 2002). Within this model, capacity is seen as the maximum amount of activation (of global processes and resources) available to maintain storage and processing of information. Capacity would be a

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Hitch, Service and Martin (1997); Jarrold, Hewes and Baddeley (2000); Willis and Gathercole (2001); Alloway and Gathercole (2005); Gathercole, Tiffany, Briscoe, Thorn and the ALSPAC team (2005).

[12] See Daneman and Carpenter (1980 in Montgomery, 1995, 2000a, 2000b, 2002a, 2002b).

function of processing efficiency hence impaired serial recall is thought to reflect slow and inefficient processing (Fazio, 1998).

Important for the current study, is the fact that both models distinguish between the size of the memory store, and its functional capacity, which would be determined by the availability and regulation of resources. Baddeley's model regards phonological working memory capacity as the ability to retain and refresh phonological information in the phonological store for a brief period of time, while the central executive controls processing operations. The Daneman and Carpenter model regards functional working memory capacity as the ability to store verbal information in short term memory while simultaneously conducting comprehension processes[13]. It is the view of this study that impaired speech production would serve as a drain on resources, hence processing may be less efficient with a resultant impact on storage.

Phonological Loop: The phonological loop of Baddeley's model is seen as a passive, limited-capacity short-term store for phonological information, with the function of providing temporary storage while cognitive tasks are being performed, such as auditory or reading comprehension or verbal reasoning. Information is rapidly lost from this store through decay or interference (time-based decay). Information in this store is composed primarily of the phonological features of stimuli, hence if phonological coding is deficient, verbal short term memory will be affected (Fazio, 1998).

There is substantial empirical support for the construct of a phonological loop, including evidence from nonword repetition tasks; the phonological similarity effect, which demonstrated differences on recall of rhyming and non-rhyming words; and articulatory suppression tasks, which prevent rehearsal (Jarrold, Baddeley & Phillips, 2002). The phonological loop has been associated with a variety of linguistic abilities in both children and adults.

[13] Within the Daneman and Carpenter model, storage is defined as the temporary retention of verbal information that has already been processed. Processing refers to the language operations generating various representations of input, including phonological, lexical, morphological and propositional representations.

It has been proposed that there is an articulatory control process, subvocal rehearsal, which serves to refresh and maintain speech material for a brief time in the phonological store, and is also capable of subvocally recoding printed material, hence registering it in the phonological store (Baddeley, 1997). The efficiency of the articulatory control process depends on the rate of rehearsal (Baddeley, 1997).

Episodic Buffer: This limited capacity system depends heavily on executive processing, but differs from the central executive in that it is concerned with the storage of information rather than attentional control. It is "episodic" in that it binds together information from a number of different sources into chunks or episodes, and it is a buffer as it provides a way to combine information from different modalities into a single multi-faceted code (Baddeley, 2003).

Important to this study is the concept that within both models, maturation is seen as an increase in functional capacity, possibly linked to increased automaticity, rather than an increase in working memory capacity per se (Fazio, 1998). For the adolescent population included in this study, the availability and management of resources would therefore be seen as more important than the size of the working memory.

Memory Deficits in SLI

Children with SLI are thought to have less capacity of their phonological store relative to age-matched and younger language-matched peers (Gathercole & Baddeley 1993 in Fazio, 1998), either because of difficulties in forming adequate phonological representations, or because these representations fade too rapidly. The memory trace may fade more rapidly in children with SLI because of impoverished phonological representations related to the discrimination difficulties noted in this population. However, phonological processing limitations have been demonstrated in children with a variety of language disorders, suggesting that difficulties with nonword repetition may be related to any language impairment, and that the specific nature of SLI is not yet clearly understood (Conti-Ramsden & Hesketh, 2003).

Alternative explanations suggest that the memory deficit is related to general processing limitations. For example, the memory trace may appear to fade more rapidly because children with SLI require more time to process information (Gillam, Cowan & Day, 1995). This view is supported by Montgomery's (2000b) findings that children with SLI process language more slowly than their age-matched peers and some younger language matched peers.

Fazio (1998) has suggested that children with SLI have reduced ability to process temporal information efficiently. In a series of studies on sentence comprehension, Montgomery (1995, 2000a, 2000b, 2002a, 2002b) concluded that children with SLI have impaired sentence comprehension as a function of their impaired syntactic knowledge and impaired functional working memory when processing demands increase. Within Montgomery's view, children with SLI have a similar memory capacity as their syntax matched peers, but they have difficulty with dual-load tasks, where they have difficulty coordinating the storage and processing of information when managing additional processing demands.

It is apparent from the above discussion, that a deficit of a memory store alone is unlikely to explain SLI fully. For example, a phonological memory deficit would not account for all the deficits seen in SLI, such as the nonlinguistic deficits. Instead it is the processing capacity linked to memory that appears to be important. Figure 3.1 thus reflects reciprocal relationships between memory and processing limitations. Within this study, memory capacity is regarded as one of the resources required for information processing. A memory deficit would reduce the resources available for processing, while processing limitations would hamper storage and processing in the memory store. SLI can thus be conceptualized as a language disorder with an impairment of working memory (probably linked to processing limitations), where the memory deficit is just one of the limitations contributing to the disorder.

There has been much debate about the direction of influence in the link between short term memory and SLI (e.g. Donlan & Masters, 2000). As will be discussed in Chapter 4, it is likely that there are reciprocal relationships between language and memory deficits, and between memory and speech deficits.

3.3.3 General Processing Limitations

Increasingly, processing limitations are proposed as the primary underlying deficit in SLI. Language acquisition is driven by general information processing abilities (Johnston, 1992). However, the mind is a limited capacity system, where capacity refers to the perceptual and cognitive abilities which determine the amount of information that can be processed and integrated in a given time period (Snyder, Dabasinskas & O'Connor, 2002). Differences in capacity may account for the differences between individuals with SLI and those with normal language abilities (Bishop, 1992).

There is ample evidence to demonstrate that children with SLI show impairments of perceptual processes such as rapid temporal processing across modalities (Leonard, 1998), memory (Gathercole & Baddeley, 1990) and attention (Hanson & Montgomery, 2002). However, there is also evidence that individuals' performance on tasks assessing temporal processing, memory or attention can be constrained by the processing demands of the tasks involved (e.g. Leonard, 1998).

As a result, limitations in general processing capacity have been implicated as a more plausible explanation for SLI than difficulties with lower level perceptual processes (e.g. Leonard, McGregor & Allen, 1992; Gathercole & Baddeley, 1990; Montgomery, 2000a, 2002a), or higher level linguistic knowledge. A performance-based account of language disorders would propose that the complexity of utterances that are comprehended or produced are limited by a number of factors, including: perceptual and motor constraints; limitations in memory and reasoning capacity; and nonlinguistic factors, such as memory, attention, processing speed, computational energy, efficiency, and the psychological mechanisms underlying speech (e.g. Evans, 2001).

Hence, language performance would not necessarily reflect language knowledge. In view of recent research findings, processing-based accounts of SLI are appearing more plausible than competence-based accounts alone. It is the view of this study that processing-based accounts have much to offer us in understanding SLI. In the

section below, models of information processing will be discussed, together with the crucial concepts of processing speed, automaticity, efficiency and trade-offs.

Models of Information Processing.

Information processing refers to the psychological processes involved in cognition (Snyder, Dabasinskas & O'Connor, 2002), including processes and structures in attention, perception, memory, concept formation, problem-solving and information management (Groome, 1999 in Snyder et al, 2002). The basic constructs of information processing involves three aspects (Montgomery, 2002c). Firstly, it involves representations or the symbolic coding and storing of information in long term memory. Secondly, it involves processes: the mental operations which generate transform and manipulate these representations. Such processes may be language-specific, where presumably each sub-domain of language (such as syntax) involves a unique set of processes; or general processes, such as verbal working memory, perceptual or temporal processes. Thirdly, there is an attentional component, reflecting the limited pool of mental resources which serve to activate or maintain knowledge (representations and processes) in an active state. The assumption is that successful task performance depends on the availability of attentional resources. Resources can be defined as the amount of effort or cognitive abilities that an individual has available to allocate to a task at one point in time (Snyder, Dabasinskas & O'Connor, 2002). If task demands exceed the available resources, performance is impaired.

In order to perform a task, an individual would have to encode the relevant information, decide on an appropriate response and then plan and execute the response motorically (Gillam, Cowan & Marler, 1998). As Montgomery (2002c) points out, the functional reality is that information processing does not consist of discrete components. Instead, these components operate in a bi-directional and interactive manner. Models of information processing therefore also include feedback and feedforward functions which serve to monitor response efficacy (Byers Brown & Edwards, 1989). While feedback functions monitor responses that have

already been produced, feedforward mechanisms serve an anticipatory function by providing an internal monitoring system which is capable of error detection prior to output. Feedback and feedforward mechanisms also interact with each other. Such mechanisms are of crucial importance in any tasks demanding speech output.

Models of information processing can adopt a structural or functional view of capacity. From a structural viewpoint, capacity refers to the amount of workspace available for the performance of complex mental tasks requiring processing and storage (Montgomery, 2002a; Hanson & Montgomery, 2002). Such viewpoints would include theories proposing that SLI results from limited phonological memory storage and capacity (such as the models proposed by Gathercole and Baddeley, 1990 or Just and Carpenter, 1992), or impaired functional working memory (Montgomery, 2000a; Ellis Weismer & Hesketh, 1996).

From a functional viewpoint, capacity is viewed as the amount of work performed within a unit of time (Montgomery, 2002a), where the speed, efficiency and power of processing routines are crucial. Johnston (1992) proposed that it is more likely that capacity is functional, rather than structural. Johnston suggested that when a task can be performed more rapidly, more efficiently and with more powerful mental schemes, capacity would be increased. In language impaired individuals, the converse would be true, where performance would be affected by the interaction among rate, efficiency and power of processing (Johnston, 1992).

The current study supports a functional view of capacity, where factors impacting on speed of processing, such automaticity and efficiency play a crucial role in explaining the deficits seen in SLI. This study therefore supports Fazio's (1998) view that maturation reflects an increase in functional capacity, linked in part to increased automaticity, rather than reflecting an increase in structural capacity.

Processing Speed

Processing speed is a critical component of information processing (Montgomery, 2002c). Since processing speed is implicit in both structural and functional models, information processing deficits can be regarded as process-

specific slowing, or general slowing (Ellis Weismer & Evans, 2002; Windsor, 2002). Process-specific slowing implies that only certain of the mental operations making a unique contribution to language performance are affected (i.e. are performed more slowly). Language impairment would thus involve language-specific processing deficits, such as subtle perceptual deficits, impaired phonological representation or storage, or poor rapid auditory temporal processing of linguistic and nonlinguistic information (Ellis Weismer & Evans, 2002). It is the view of this study that speech production may be one of the processes that are involved and that impaired speech production would slow overall processing. Task complexity would therefore be influenced by the nature of the task and the processes required. Authors such as Windsor (2002) would propose that several information processing skills are deficient in language impaired individuals.

In contrast, other authors have implicated generalized deficits in processing capacity, affecting both verbal and nonverbal abilities. One such perspective is the general slowing hypothesis which proposed that an individual has difficulty executing mental operations efficiently (Leonard, 1998), and that processing by children with SLI is proportionally slower than that of normal language peers. Language impairment in this perspective does not involve specific linguistic operations, but rather involves slower execution of both linguistic and nonlinguistic mental operations (Miller, Kail & Tomblin, 2001), because global developmental mechanisms drive performance more than specific mental operations or stages of information processing (Windsor, 2002). Task complexity is thus determined by the number of mental operations required by the task, rather than the nature of the task.

A general slowing hypothesis is attractive, as it accounts for the diverse research data regarding deficits seen in individuals with SLI, but it does not explain why language is particularly impaired, in that slowing is more evident in the language domain, and some linguistic processes are particularly slow (Windsor, 2002). Furthermore, not all children with SLI have difficulties with all mental operations or all aspects of language processing. The heterogeneity of the SLI population, particularly with regard to their language profiles would not support a single

mechanism, such as a general slowing hypothesis. It is more likely, as Ellis Weismer and Evans (2002) suggested that in any child or subgroup with SLI, multiple factors would contribute to the language disorder.

It is therefore the view of this study, that individuals with SLI have slowed processing due largely to deficits in specific mechanisms, including impaired speech production and motor coordination which may contribute to their language deficits.

Several studies have demonstrated that children with SLI are slower than their age-matched and language-matched peers to process language, even when they have the same underlying language knowledge (Montgomery, 2002c). Such findings would suggest that children with SLI are less efficient in their use of knowledge and processes. There is also substantial evidence that slowed processing within a limited capacity system could result in a range of linguistic deficits, including: omission of morphemes (Bishop, 1994); production of morphemes (Leonard, Eyer, Bedore & Grela, 1997); reaction time in grammaticality judgements (Montgomery & Leonard, 1998); syntactic comprehension deficits (Montgomery, 1995, 2000a; Frazier Norbury, Bishop & Briscoe, 2002); difficulty retaining and using well-specified phonological representations (Gillam, Cowan & Marler, 1998); naming speed (Lahey & Edwards, 1999); and real-time lexical comprehension (Montgomery, 2002a). Children with SLI also tend to have slower reaction times on a number of tasks, compared to typically developing peers (Lahey, Edwards & Munson, 2001), while their word learning is influenced substantially by variations in speaking rate (Ellis Weismer & Hesketh, 1996), both of which can be related to processing limitations.

It should be noted, however, that not all language impaired children have a slower speed of processing, and that there are considerable differences among individuals and among subgroups (Windsor, 2002).

Efficiency and Processing Tradeoffs

In both a structural and a functional perspective of information processing, or a process-specific versus a general slowing perspective, processing breakdowns occur if task demands exceed the available processing capacity. When complex tasks are

performed, processing trade-offs occur (Johnston, 1992). For example, there could be a trade-off between storage and processing, where processing would take precedence over storage, resulting in the loss of information from working memory (Baddeley, 1997). As task demands increase, capacity constraints would be reflected by linguistic trade-offs: for example, speech production errors may occur or words may be omitted when grammatical complexity of an utterance is increased. For example, correct use of morphological markers could vary depending on linguistic context in children with language impairments (Masterson & Kamhi, 1991 in Hadley, 1998; Evans, 1996 in Leonard, 1998).

Alternatively there could be a time-accuracy trade-off (Ellis Weismer & Evans, 2002; Snyder, Dabasinskas & O'Connor, 2002), resulting either in faster but less accurate responses, or slower, more accurate responses. Performance would therefore vary as a function of the familiarity of information, the linguistic complexity of the task, and the pressure of the communicative situation: The efficiency with which linguistic knowledge is accessed and utilized can therefore be evaluated by considering the accuracy and latency of responses (Ellis Weismer & Evans, 2002).

Automaticity

Automaticity can be defined as the ease or efficiency with which knowledge can be retrieved or manipulated (Field, 2004). The automaticity with which mental operations can be carried out, will affect performance (Windsor, 2002), as speed of processing is a crucial component of an information processing perspective. The degree of automaticity with which a language task is performed may vary according to the demands of the task (Field, 2004). Accordingly, capacity has been linked to the automaticity of skills and cognitive operations. When a task is performed automatically, conscious attention is not allocated to processing, and higher levels of conscious processing are not engaged, resulting in fewer processing demands (Snyder, Dabasinskas & O'Connor, 2002). As automaticity increases, cognitive resources are freed, which in turn increases processing capacity (Kamhi, 1996). In contrast, controlled processes are cognitive activities which are performed

consciously and intentionally, thus placing greater demands on cognitive resources (Snyder et al, 2002).

Capacity limitations can therefore be related to a range of factors (Ellis Weismer 1993 in Kamhi, 1996), as lack of automaticity in any one area would place a greater strain on resources. As Montgomery (2002c) pointed out, the performance limitations seen in SLI could reflect deficient knowledge but adequate processing for some children; and adequate knowledge or representations, but inefficient processing for other children; or a combination of deficient representations and inefficient processing.

Adolescents are likely to have increased automaticity compared to children, without having achieved adult levels of efficiency, as development affects automaticity. It is assumed that in adults, lower-level mental operations require less working memory capacity, as these tasks are carried out automatically, thus freeing resources for higher-level processing. As children have not yet developed such automaticity, tasks are more demanding of working memory capacity, with the result that their language performance is less rapid and fluent than that of adults (Windsor, 2002). As mental operations become more developed, performance becomes more automated and efficient, leading to improved performance on timed tasks. Adolescence would therefore represent a mid-point in development of automaticity.

It is widely accepted that processing limitations may account for some (if not all) of the deficits seen in SLI. However, with the exception of working memory and processing speed, little is known about the specific mechanisms within the information processing process. The current study aims to add to our understanding of one component of information processing in language, namely speech production.

3.3.4 Processing Limitations: Speech Production and the Threshold Effect

The limited processing capacity theories have focused largely on cognitive-linguistic processing limitations as an explanation for SLI. Bishop (2000) reported that there is mounting evidence for structural anomalies affecting the language areas

of the brain in individuals with SLI. It is possible that such structural anomalies are not only affecting cognitive-linguistic processes, but also motoric processes.

In the previous section, the first hypothesis of this study was presented: namely that speech production is often impaired in individuals with SLI. A second hypothesis is that children with SLI present with subtle neurological deficits, manifested in part in motor impairments, which affect their speech production, and which may impact on language processing.

The idea that children with SLI may present with neurological differences in comparison to peers is not a new one. Johnston (1991) pointed out language impaired children may differ from typically developing children on neurological and physical variables, as all patterns of human behaviour and mental function are presumed to have neurological or other physical correlates. In a previous section (3.2.3) the occurrence of motor deficits in individuals with SLI was discussed. The hypothesized contribution of motoric and speech deficits to a threshold effect will now be presented.

The Threshold Effect

Gillam, Hoffman, Marler & Wynn-Dancy (2002) described a threshold effect to account for language impairment. They proposed that subtle deficits throughout the language processing system interact, and that limitations at one level affect processing at another level. Each deficit on its own may not affect processing, but it is the interaction of deficits that increases the likelihood of impaired or slowed processing, particularly when resource demands increase. It is proposed in this study that for many children with SLI, speech production, including the motoric component of speech production, is one of these subtle deficits, which interacts with other deficits throughout the language processing system, resulting in inefficient or slower processing.

It has been suggested that performance on any task, but particularly linguistic tasks, can be limited because of three factors (Snyder, Dabasinskas & O'Connor, 2002): Firstly, the available data may be limited, for example as a result of a hearing

loss. In children with SLI, this would not be the case. Secondly, performance may be limited by the resource demands of the task. If a task is resource-demanding, performance would deteriorate if those resources are required elsewhere. Thirdly, performance may be limited by the capacity the individual brings to the task, where language impairment may reflect a limitation in capacity (Ellis Weismer & Hesketh, 1996). Thus an individual's processing strengths and weaknesses may selectively limit performance.

It is the view of this study that the second and third factors would interact in children with SLI. In particular, it is possible that children with SLI may have sufficient capacity for adequate performance of most perceptual, linguistic and cognitive tasks under optimal conditions (Gillam, Hoffman, Marler & Wynn-Dancy, 2002). For example, assessing speech production in a relatively simple task such as picture naming, may not reflect subtle speech production difficulties, as sufficient resources can be allocated to this task. When speech production is required in a more complex task, where faster on-line processing or multiple mental steps are required (Gillam et al, 2002), such as producing a nonword, repeating a complex sentence, or producing a narrative, resources would be divided among a number of demanding tasks. If speech production is not sufficiently automatic, resources would have to be allocated to speech, thus diverting resources away from other processing operations, such as working memory or language formulation. While it is unlikely that speech production difficulties would be the sole reason for poor performance on tasks requiring verbal output, it is hypothesized that speech production would be a drain on resources and interact with other deficits to constrain performance.

Impairments in speech production, even if these are subtle, would hamper the efficiency of information processing in tasks requiring verbal output. Time-accuracy trade-offs may have to occur, where either accuracy or the latency of responses are compromised. Since linguistic tasks are complex, involving simultaneous processing of semantic, syntactic, morphological and phonological components, speech production deficits may not necessarily result in speech errors. If resources are diverted to maintain adequate speech output, errors may be evident in other aspects of

language processing, such as morphological errors. Alternatively, in order to maintain accurate speech, responses may be slower, allowing more time for phonological processing and planning of speech output; while errors detected through feedforward processes may also slow the response rate. Slower responses would affect working memory, which would have to maintain information for longer periods before verbal responses are complete.

Studies which have concluded that any speech deficit seen in children with SLI plays either no role or a very limited role in constraining their performance on verbal output tasks have not considered task demands or levels of automaticity. For example, in a study by Gillam, Cowan and Marler (1998), which concluded that speech output processes did not influence working memory performance, digits were used to assess memory. In assessment of adult patients with neurogenic communication disorders, counting is regarded as automatic speech, and it can be assumed that digits require minimal phonological encoding because of their high levels of automaticity. Using such stimuli, which would not require substantial resources for speech output, do not provide an accurate picture of the effect of speech production processes on more demanding stimuli.

3.4 Risk Factors for Specific Language Impairment

Any description of the nature of SLI should include a consideration of the origins of the disorder, as one of the aims of science is to go beyond description, in order to provide explanation. There are compelling reasons to investigate causation in communication disorders. There is a clinical responsibility to caregivers who look to clinicians to explain why their child has a speech or language disorder (Aram, 1991; Tomblin, 1991); while an understanding of cause may also impact on intervention (Aram, 1991; Shriberg, Kent et al, 2003; Shriberg, 2004), prevention (Tomblin, 1991; Shriberg, 2004) or early identification, and the ability to make prognostic statements (Tomblin, 1991).

As SLI is such a heterogeneous disorder, it is likely that it has more than one etiology. It has been suggested that the etiology of SLI is multifactorial (Lahey &

Edwards, 1995), with an early neurodevelopmental onset (Tomblin, Smith & Zhang, 1997). In line with suggestions by Bishop (2002a), the current study proposes that speech and language are such robust abilities that more than one risk factor is required for impairment to occur. In view of this study's emphasis on motoric factors in speech production, risk factors focused on in this study are primarily those which could contribute to subtle neurological deficits. Furthermore, the emphasis was on risk factors which have been associated with speech disorders, namely pre- and perinatal complications, ENT difficulties and positive family history of the disorder (Fox, Dodd & Howard, 2002). In the section below, the risk factors for SLI and for the speech disorders which formed the focus of the current study will be discussed. The risk factors have been divided into familial risk factors (pointing to a genetic etiology); neurodevelopmental risk factors, including Attention Deficit (Hyperactivity) Disorder (ADHD) and significant early history; and otitis media with effusion.

3.4.1 Genetic Factors

Both SLI and Developmental Phonological Disorders (DPDs) have a strong genetic contribution to risk factors. Genetic factors in both SLI and DPD have been investigated through family aggregation studies, twin studies, adoption studies and epidemiological studies. In the section below, findings from these studies will be discussed, together with findings regarding subtypes, gender bias, and the mechanisms for genetic influence. Methodological concerns regarding genetics research in these disorders will also be considered.

Both disorders tend to aggregate in families (Bishop & Edmundson, 1987; Lahey & Edwards, 1995; Rice, Haney & Wexler, 1998; Tomblin, Freese & Records, 1992; Benasich & Spitz, 1999; Bishop, 2002a; Felsenfeld, 2002; Shriberg, 2004). Of children with a positive family history of SLI, 20-40% have language deficits, compared to 4-7% of the general population (Choudhury & Benasich, 2003). Similarly, approximately 20-41% (Felsenfeld, 2002) or 20-60% (Shriberg, 2004) of

first degree relatives of speech delay probands[14] are also affected. Family studies have shown that families of proband children with DPD had more speech, language and reading problems than families of control cases (Lewis, Ekelman & Aram, 1989); and children of DPD probands performed more poorly on measures of expressive language and articulation than children of controls (Felsenfeld, McGue & Broen, 1995).

Twin studies have provided strong support for a genetic basis for both disorders. Concordance of SLI is much higher in monozygotic than dizygotic twins (Bishop, North & Donlan, 1995; Tomblin & Buckwalter, 1998). Bishop, North and Donlan's (1995) twin study, which included several phenotypes of articulation and language deficits, found higher concordance rates for monozygotic than dizygotic twins (.70 and .46 respectively). A twin study by Lewis and Thompson (1992) found that monozygotic twins were significantly more concordant for the presence of speech disorder (0.86) than dizygotic twins (0.48). Their study also found that when twins were concordant for speech and language disorders, a higher incidence of first degree relatives with language problems were reported.

An adoption study by Felsenfeld and Plomin (1997) reported that children of parents with speech disorders were at an increased risk for speech disorders, even when they were adopted away from the affected parent(s) at or near birth; while a large scale epidemiological study (Tomblin, Records, et al, 1997) found that SLI is more often associated with genetic factors than with pre- or perinatal risk factors.

Genetic factors have also been investigated in specific subgroups of SLI and DPD. Studies on specific subgroups of SLI, have suggested that children with expressive language deficits are more likely to have a positive family history than children with both receptive and expressive deficits (Lahey & Edwards, 1995), with the exception of a study by Whitehurst et al (1991), which they felt argued against a genetic cause of expressive language delays. However, the Whitehurst et al study investigated very young children (mean age 28 months), where it was probable that

[14] A proband is a person affected by a particular condition or disorder, who is used as the starting point for a study on familial aggregation of that disorder.

not all participants had a confirmed diagnosis of SLI. Results of this study may thus be questionable. A second subgroup which appears to have a significant genetic etiology, is that of Grammatical SLI, where the pattern of impairment in relatives of probands is suggestive of an autosomal dominant inheritance pattern (van der Lely & Stollwerck, 1996). Expressive language deficits may be linked, in part, to output factors such as speech production, thus one could hypothesize that children with expressive deficits are more likely to have speech deficits, which could then lead to the hypothesis that children with SLI and speech deficits are more likely to have a genetic etiology.

Shriberg (2004) described some of the emerging epidemiological findings for a subtype of DPD, speech disorders of genetic origin (SD-GEN), which suggest some overlap with the SLI population. He reported that the probability of an associated expressive language disorder was 40-60% at ages 3-6 years, decreasing to 10-15% at age 6 years. Typically, these children present with primarily natural phonological process errors, and may experience difficulty on tasks assessing phonological working memory. Both these characteristics would suggest an overlap with the SLI population, where language use in specific areas is typically delayed, rather than deviant, and impaired phonological working memory is regarded as a key characteristic.

As speech delay appears to normalize in many children, it has been suggested that differences in outcome (early recovery versus persistence) may reflect different genetic profiles (Felsenfeld, 2002). Alternatively, the manifestation (phenotype) of phonological disorder may change with development (Lewis & Freebairn, 1992). This hypothesis may also apply to SLI.

The possibility of a gender bias has been investigated in both SLI and DPD. Shriberg reports that, as with SLI, more boys than girls present with SD-GEN, with prevalence estimates ranging from 2:1 or 3:1 in preschool, to 1.5:1 at age 6 years, which is similar to the prevalence estimates provided for SLI (Leonard, 1998; Tomblin, Records, et al, 1997). Several studies on SLI (e.g. Tomblin, 1989; Bishop et al, 1995) found a gender bias in relatives, with many more male relatives than

females being affected, although Rice, Haney and Wexler (1998) found equivalent rates of brothers and sisters affected in their investigation of probands showing an EOI stage. Tomblin, Smith and Zhang (1997) reported that paternal, rather than maternal history of speech or language difficulties was highly associated with SLI, with 24.5% of fathers and only 17.5% of mothers in their large scale study reporting a history of speech problems, mental retardation or learning disability. Van der Lely and Stollwerck's (1996) study was unusual in finding a similar ratio of male and female affected siblings, leading to their conclusion of autosomal rather than sex-linked inheritance. However, the van der Lely study was based on a very small sample size (12 probands), suggesting that results should be interpreted with caution.

Other studies which investigated the incidence of affected relatives for probands with SLI, reported 20-37% affected mothers; 18-43% affected fathers, and 29-39% affected siblings (Tomblin, 1989; Lewis, Cox & Byard, 1993; Whitehurst et al, 1991, Tallal, Ross & Curtiss, 1989). However, as Rice, Haney & Wexler (1998) pointed out, results should be interpreted with caution as there appears to be instability from one study to another of estimates of risk for fathers versus mothers and sisters versus brothers. For example, the Tallal et al (1989) study has been criticized for not excluding speech impairments as 60% of the sample had significant articulation deficits. As Rice et al (1998) pointed out, it is not possible to know if what is moving through families is a limited capacity for phonological representations or motor speech production, which would concur with findings from studies on families of children with speech disorders. It would therefore be interesting to compare the rate of affectedness in families of children with SLI with and without significant speech disorder.

Multiple loci or genotypes appear to be implicated in both disorders, indicating the likelihood that there are many different genes whose disruption can lead to speech and/or language impairments, and possibly suggesting different genetic etiologies for different subgroups (Bishop, 2002a; Shriberg, 2003), thus further complicating comparison among studies. Felsenfeld (2002) proposed that speech delay may be related to a polygenic transmission model, where multiple genes are implicated.

Similarly to SLI, speech delay may have variable expression, with some subgroups having mild or subclinical variants, and others having high recovery rates. Such findings may further point to the possibility of genetic heterogeneity (Felsenfeld, 2002).

In both SLI and DPD there is the question as to what is inherited. Some characteristics of SLI appear to be more susceptible to genetic influences than others. For example, Bishop's (2002a) twin study demonstrated that auditory processing deficits in children with SLI showed no evidence of genetic influence, whereas nonword repetition was highly heritable. D.V.M. Bishop, S.J. Bishop et al (1999) suggested that genes are the principal factor determining whether children are at risk for language impairment, but that the severity of the expression of that risk is modulated by other factors, such as auditory processing skills, which appear to be determined by environmental factors.

The mechanism for genetic influence in speech disorders is also not known. Lewis and Thompson (1992) proposed that children either inherit a similarity in structure and function of the articulatory mechanism, or that they share similar cognitive processing skills. Lewis and Freebairn (1997) found that poorer oral motor coordination and productive phonology may distinguish individuals with familial phonologic disorders from individuals with phonologic disorders of unknown origin. However, their study did not find significant group differences on measures of articulation, phonology, language and oral motor skills. The genetic heterogeneity of familial phonological disorders (Felsenfeld, 2002) could account for this finding: there may be different phenotypes related to different genes. Behavioural deviations such as speech and language disorders, may also reflect neuroanatomical alterations, which has been confirmed by imaging studies and anatomical studies which have shown microscopic neurological deviations (Crary, 1993).

While twin and adoption studies have provided support for genetic contributions to SLI, the influence of environmental factors cannot be excluded. Tomblin and Buckwalter's (1998) twin study found a heritability factor of .45, suggesting a moderate degree of environmental influence and supporting a multifactorial etiology

for SLI. Lewis and Freebairn (1997) proposed a threshold hypothesis, incorporating genetic and environmental influences for DPD. Thus certain individuals may have a higher genetic loading, which may be triggered by environmental conditions. The same explanation may hold for SLI. Environmental influences are most likely to be some of the other risk factors discussed in this chapter. The influence of parenting behaviours or communicative input factors as a primary causal or contributive factor to language difficulties has been largely discounted (Leonard, 1987; Hammer, Tomblin, Zhang & Weiss, 2001), although such factors may interact with other primary risk factors.

There is thus much evidence for the heritability of SLI and DPD, although genetic factors may just be part of a multifactorial etiology. It is probable that environmental factors may interact with a genetic etiology to increase or reduce the likelihood that a child would present with speech and/or language difficulties. Alternatively, as Rice, Haney and Wexler (1998) suggest, the same underlying neurocognitive mechanisms may be implicated, regardless of whether the biological contributor is genetic or environmental. The hypothesis of the current study is that subgroups of SLI and subgroups of DPD have a genetic contribution to the disorder. It is possible that individuals with a genetic etiology are more likely to present with a persistent form of the disorder, particularly if motor skills are involved.

Methodological Concerns in Genetics Research

There are methodological concerns regarding the study of genetic factors in SLI and DPD. Genetic studies in the areas of SLI and DPD have been hampered by the heterogeneity of the populations and the consequent lack of clear description of a phenotype, as methods used to study pedigrees are very sensitive to errors in phenotypic description (Tomblin, Freese & Records, 1992; Rice, Haney & Wexler, 1998; Shriberg, 2003). In both disorders, diagnostic gold standards are lacking, with some studies using very broad inclusion criteria, such as reading disorder (Felsenfeld, 2002). It is therefore difficult to compare findings from different studies.

To date, most studies have tried to separate studies starting with probands with significant speech disorders, from those with probands with language impairments (Rice, Haney & Wexler, 1998). Even when probands are selected who apparently only have a language or a speech disorder, affected relatives present with a mixture of speech and language disorders (e.g. Rice et al, 1998), suggesting that such a separation is perhaps artificial. The current study proposes that even language impaired probands with no apparent speech disorder as measured on these studies, may not be free of speech impairment, which may explain some of the above results. Such separation of studies may therefore not accurately reflect separate phenotypes.

Studies reporting rates of affectedness in families have to be evaluated carefully, as some studies relied on direct testing of relatives (the preferred method) (e.g. Spitz, Tallal, Flax & Benasich, 1997), while others relied on interviews with a family informant (e.g. Rice, Haney & Wexler, 1998). There were also methodological differences within studies relying on interviews, where some used broad questions (for example: Does anyone in the family have a speech, language or hearing deficit?), and others required informants to answer questions about each relative separately (e.g. Rice et al, 1998). Such methodological differences could yield different results.

3.4.2 Neurodevelopmental Factors

Attention Deficit (Hyperactivity) Disorder (AD[H]D)

Attention[15] is one of the primary resources required for linguistic processing, and as such it is important to investigate attention deficits as a potential risk factor in persistent SLI. Attention Deficit (Hyperactivity) Disorder (AD[H]D) [16] is a chronic developmental disorder that is seldom outgrown (Barkley, 1998), and is thought to have a neurological basis. There is increasing evidence that children with AD(H)D

[15] Attention can be defined as "…the willed or voluntary selection of a topic to hold within consciousness, utilizing short term memory in order to allow mental processing (thinking). Attention is the focusing of conscious awareness upon i) a particular motor activity – especially while it is being learned; ii) a specific sensory input or perception; or iii) memories and concepts retrieved from long-term memory stores into short-term memory" (Brown & Minns, 1999, p. 50).

[16] AD(H)D is characterized by an inability to sustain attention, motoric hyperactivity, and impulsivity inappropriate to an individual's chronological age (Keller & Tillery, 2002).

present with underarousal of the central nervous system, linked particularly to the frontal lobes (premotor cortex and superior prefrontal cortex) (Keller & Tillery, 2002).

It is important to document the attentional abilities of participants in any study requiring information processing as attention is an important resource in any task requiring language processing (Evans, 2001). Children with language impairment have been found to have slowed orientation of attention to complex auditory information, problems shifting the focus of their attention, and a limited capacity to sustain focus (Gillam, Hoffman, Marler & Wynn-Dancy, 2002), while a recent fMRI study on adolescents with SLI found significant hypoactivity in areas related to attention during language processing (Ellis Weismer, Plante, Jones & Tomblin, 2005). Should attention be limited in children with SLI, it would reduce an important resource for processing and place additional strain on a system that possibly already has a limited processing capacity, thus contributing to a threshold effect.

Focused attention has also been identified as a precursor to motor learning (Caruso & Strand, 1999), suggesting that children with attention deficits would be challenged with regard to allocating resources to motor speech production.

It is acknowledged that attentional problems may occur commonly in children with SLI (Leonard, 1998), yet few studies in the area of SLI have documented how many participants presented with AD(H)D. When this has been done, there appears to be a high co-occurrence (50% or higher) of SLI and AD(H)D (e.g. Redmond & Rice, 1998; Kovac, Garabedian, Du Souich & Palmour, 2001; Cantwell, 1996 in Kovac et al, 2001). Measures of attention can differentiate between children with SLI and controls (Kovac et al, 2001), while attention deficits have been associated with global deficits in speech and language (Beitchman & Inglis, 1991 in Lahey & Edwards, 1995), and with mixed receptive-expressive SLI (Lahey & Edwards, 1995).

Children with persistent SLI may be more likely to present with AD(H)D in addition to the language disorder. There is a high co-occurrence of AD(H)D and learning disabilities, ranging from 10-92% (Biederman, Faraone & Kiely, 1996). Similarly, it has been found that dyslexia and SLI are potentially comorbid (Catts,

Adlof, Hogan & Ellis Weismer, 2005). Thus the triad of disorders (dyslexia, SLI and AD[H]D) may co-occur in some individuals.

As will be discussed below, SLI is thought to have a strong genetic basis. As yet, it is not clear exactly what is inherited in families with SLI. Twin studies have shown concordance of poor concentration and distractibility, suggesting a genetic basis for AD(H)D (Brown & Minns, 1999). Kovac, Garabedian, Du Souich and Palmour (2001) also reported that SLI probands with AD(H)D had a significantly higher chance of having relatives with speech/language impairments than SLI probands with no history of AD(H)D. It is thus possible that there may be a specific genetically based etiological subtype or phenotype of SLI, characterized by concomitant AD(H)D.

This study does not suggest that AD(H)D has a causal relationship with SLI. Instead, it is hypothesized that these two conditions often co-occur, and that attention may be one of the resources implicated in resource-limited or processing limitations explanations of SLI. It is therefore important to investigate AD(H)D as a potential risk factor for children with persistent SLI and speech difficulties.

Early History Risk Factors

It is the hypothesis of this study that for some subgroups of SLI, particularly persistent SLI, pre- and perinatal risk factors play an etiological role. At present there is little evidence to suggest that SLI is related to pre- and perinatal risk factors. However, the existing studies regarding SLI primarily focused on cross-sectional studies of preschool groups, which were often not divided into subgroups of SLI. It is acknowledged that even in the literature regarding specific learning disabilities, children with a pre- or perinatal etiology form only a small subgroup. However, this study contends that it is precisely this group who is highly at risk for persistent SLI.

Although there has been substantial research regarding the effects of pre- and perinatal risk factors[17] on language and cognitive development, very few studies have

[17] Pre- and perinatal risk factors could include foetal exposure to alcohol, tobacco or illicit drugs; maternal age; exposure to infectious diseases in utero; oxygen deprivation in the perinatal or neonatal periods; and low birth weight.

investigated SLI as an outcome of these risk factors. Thus, while the association between these factors and general cognitive deficits has been well-documented, little is known about the relationship between these risk factors and SLI. One exception is the study by Tomblin, Smith and Zhang (1997), which compared 177 children with SLI to 925 typically developing peers. Their study found that the only significant prenatal factor was paternal smoking; while SLI was not associated with maternal substance abuse or smoking, low birth weight, type of delivery, induction of labour, or labour and delivery complications. Similarly, Lahey and Edwards (1995) reported that complications of pregnancy or birth, birthweight, or maternal age did not differentiate children according to family history or subgroup (expressive or mixed disorder). However, both these studies involved preschool children and did not differentiate between participants with resolving versus persistent SLI. It is the hypothesis of this study that different risk factors may apply to particular subtypes, such as persistent SLI.

In contrast, Rice, Spitz and O'Brien (1997) conducted a follow-up study of a group of children who had been admitted to a neonatal intensive care unit (NICU). Of the sample of 34 children, 53% showed language and/or speech impairments at age 4 years. Rice et al concluded that perinatal risk can contribute to grammatical limitations, such as EOI.

It is significant that the studies done on risk factors in SLI have focused primarily on cross-sectional studies of preschool groups, with the exception of the Rice et al (1997) longitudinal study. The findings reported in literature in SLI contradict those found in literature regarding specific learning disorders, where the consensus appears to be that pre- and perinatal factors can contribute to the development of learning disorders (Hadders-Algra & Lindahl, 1999) although few studies have investigated the effects of pre- and perinatal risk factors beyond the age of 6 years, when learning disabilities would usually first become apparent. Low birth weight and foetal exposure to toxic substances have definitely been associated with learning disorders. Since learning disorders may be comorbid with SLI, these factors could also apply to persistent SLI.

Hadders-Algra & Lindahl (1999) reported on four studies[18] which evaluated long-term development in mixed groups of neonates, which all found a contribution of perinatal adversities to the development of learning difficulties. The Helsinki study suggested that both hereditary and environmental factors played an important role in the development of learning disabilities. The Groningen project reported that the risk of developing Minor Neurological Dysfunction (MND)[19] (which is often a feature of specific learning difficulties) was closely related to perinatal factors.

Only 20-30% of children with learning disorders appear to have a perinatal etiology, with evidence suggesting that prenatal adversities are more likely to result in a severe disorder (such as cerebral palsy), whereas adversities in the last trimester to the age of two years are more closely associated with milder problems such as MND or learning disabilities (Hadders-Algra & Lindahl, 1999).

It is likely that for children with SLI, pre- and perinatal risk factors seldom occur in isolation, but that they may contribute to a multifactorial etiology of SLI, particularly for more severe or persistent subgroups of SLI. Hence studies which have focused on preschool populations have not been able to isolate the influence of pre- and perinatal risk factors in groups containing both resolving and persistent subgroups of SLI. Consequently, it was felt to be important to investigate early risk factors specifically in a persistent SLI group. Furthermore, the presence of MND or Developmental Coordination Disorder (DCD) may contribute to subtle motoric problems which could affect speech production. Since pre- and perinatal risk factors are associated with MND and DCD (Sugden & Wright, 1998) and with speech disorders (Fox, Dodd & Howard, 2002), it would be important to investigate these risk factors in a study on speech production.

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[18] Werner and Smith (1979) followed a Hawaii cohort to age 18 years; Nichols and Chen (1981) in the US National Collaborative Perinatal Project followed a cohort for 20 years; the Helsinki Neonatal Risk Study (Michelson & Lindahl, 1993) followed 386 infants to age 9 years; and the Groningen Perinatal Project is following a birth cohort of 3162 children.

[19] The Groningen Perinatal Project used the following signs to diagnose Minor Neurological Dysfunction (MND): posture and muscle tone; reflexes; choreiform dyskinesia; coordination and balance; fine manipulative ability; and dysfunction of a cranial nerve or presence of excessive amounts of associated movements (Hadders-Algra et al, 1988, in Hadders-Algra & Lindahl, 1999).

3.4.3 Otitis Media with Effusion

Despite largely inconclusive findings regarding the role of otitis media with effusion as a risk factor for speech and language deficits, its potential contribution cannot be ignored. Otitis media with effusion is a risk factor for speech and language delay, as the perceptual deficits associated with fluctuating hearing loss pose a risk to the formation of stable underlying phonological representations (Shriberg, Flipsen, Kwiatkowski & McSweeny, 2003), specifically affecting the establishment of correct place for obstruents (Shriberg, Kent et al, 2003). These representations underlie all verbal learning. However, there is evidence that otitis media with effusion is more likely to be associated with minor impairments of language than with serious language disorders (Rutter, 2000).

Studies regarding otitis media alone as a risk factor for speech and/or language impairment are largely inconclusive (Bishop, 1992; Byers Brown & Edwards, 1989; Shriberg, 2004), and the consensus appears to be that otitis media with effusion or fluctuant hearing loss alone is not a significant etiological factor for either SLI or speech sound disorders (e.g. Paul, Lynn & Lohr-Flanders, 1993; Grievink, Peters, van Bon & Schilder, 1993). In a review of articles published between 1969 and 1997, Shriberg, Flipsen et al (2000 in Shriberg, Flipsen, Kwiatkowski and McSweeny, 2003, p.508) concluded that "…support for a *correlative* association between early otitis media and concurrent or later SD was equivocal, and support for a *causal* association remained undocumented". A review of articles published between 1997 and 2002 reported modest or transient effect sizes when reporting that otitis media with effusion poses increased risk for speech-language delay or other verbal behaviours (e.g. reading); while studies following large cohorts of children in Pittsburgh and Chapel Hill, have reported negative findings for otitis media with effusion as a risk factor of speech-language acquisition (Shriberg, Flipsen et al, 2003). A more recent longitudinal study following infants from birth to three years of age, reported that persistent otitis media with effusion was negligibly associated

with, and probably did not affect developmental outcomes[20] at 4 years of age (Paradise et al, 2003).

Most studies regarding the relationship between otitis media with effusion and speech and/or language development are beset with methodological difficulties. Retrospective studies have not been able to document the severity and frequency of otitis media or levels of hearing loss; while prospective studies have used a wide variety of measures to evaluate speech and language ability, not all of which were effective in detecting language impairment.

Shriberg and colleagues have identified a subtype of speech delay related to otitis media with effusion (SD-OME), which occurs in approximately 30% of preschoolers with speech delay and appears to be associated with greater unintelligibility than expected for a child's speech status, possibly because of an interaction with language variables (Shriberg & Austin, 1998). Two alternative explanatory accounts for SD-OME exist (Shriberg, Flipsen, Kwiatkowski & McSweeny, 2003). An acoustic-phonetic account proposes that children with otitis media fail to discriminate, store and reproduce the subtle acoustic contrasts required to track meaning, resulting in unintelligible speech. The mediated account (supported by findings from the Shriberg, Flipsen et al study) proposed that the fluctuant hearing loss has diffuse cognitive-linguistic effects, which would influence speech perception and production. Of particular interest to the current study, is the mediation of concurrent language status on the effects of early fluctuant hearing loss on later speech status (Shriberg, Friel-Patti et al, 2000 in Shriberg, Flipsen et al, 2003). Such a finding would support a multifactorial model for speech and/or language delay.

Using a mediated account to explain the relatively higher consonant accuracy of children with SD-OME in the presence of poorer intelligibility (compared to other types of speech delay), Shriberg, Flipsen et al (2003) suggest that while only certain early developing sounds are directly affected by the intensity-frequency deficits associated with otitis media, these earlier emerging sounds mediate the emergence of

[20] Outcomes measured in the Paradise et al (2003) study included: general cognitive ability, receptive vocabulary, receptive grammar, nonword repetition, word diversity, mean length of utterance (morphemes), and speech (Percentage Consonants Correct-Revised).

later speech sounds. Thus otitis media affecting a small number of early developing sounds can produce widespread speech delay.

Medical risk factors such as otitis media with effusion (OME) are unlikely to be the primary etiological factors for SLI or speech sound disorders. Nevertheless the contribution of otitis media with effusion to a multifactorial etiology of SLI or speech sound disorders cannot be discounted (Bishop, 1992; Shriberg, Flipsen et al., 2003; Shriberg, 2004), and it is possible that the combination of otitis media with effusion and risk factors such as perinatal adversities could have more severe consequences than either factor in isolation (Bishop, 1992; Lahey & Edwards, 1995; Tomblin, Smith & Zhang, 1997). Certainly, descriptive linguistic studies have provided support for both quantitative and qualitative differences in speech acquisition associated with otitis media or fluctuant hearing loss (Shriberg, 2004), and large-scale epidemiological studies have supported a multifactorial risk model for speech delay (Shriberg, Flipsen et al, 2003).

There may be an interaction between genetic factors and the occurrence of otitis media. Families with a positive history of SLI reported higher incidences of autoimmune diseases (35%) compared to families with no history of SLI (9%) (Choudhury & Benasich, 2003). This finding correlates with that of Lahey and Edwards (1995) who reported that children with a positive family history of SLI were more likely to have had at least one serious childhood illness or recurrent otitis media than children with a negative family history.

It is the hypothesis of this study that the speech difficulties encountered by children with SLI are related (in part) to motor disturbances originating from genetic and/or pre- and perinatal factors, although otitis media may contribute to a multifactorial etiology. There is sufficient evidence linking otitis media to speech and language development to indicate that this factor could not be ignored in the current study. At the same time, the retrospective design of this study made it unlikely that sufficient information would be obtained about the participants' history of otitis media to come to clear conclusions regarding the impact of this risk factor on speech and language development in adolescents.

3.4.4 Summary and Conclusions Regarding Risk Factors

At this point there is strong evidence for a genetic contribution to SLI and DPD in a large number of children with these disorders, although not all children with SLI and DPD report positive family histories of speech, language or learning problems. However, gene expression can be influenced by environmental factors, and there is likely to be an interaction between genetic factors, biologic factors, and cultural environmental factors (Tomblin, Smith & Zhang, 1997). There is also evidence for a multifactorial etiology for SLI and DPD, with factors such as family history interacting with other factors, such as illness (Lahey & Edwards, 1995), environment (D.V.M. Bishop, S.J. Bishop et al, 1999) or possibly, pre- and perinatal risk factors.

It would appear that similar risk factors are implicated for SLI and DPD, which is not surprising, considering the large overlap in the two disorders. While most studies have focused on the influence of risk factors on either SLI or DPD, few have investigated populations who have both disorders. The question has to be asked whether children with persistent SLI, particularly if they have residual speech difficulties, have a different profile of risk factors to that identified in younger groups of children with SLI, who have often not been differentiated in terms of subgroups.

3.5 Methodological Considerations

The preceding discussion highlighted several important issues which were taken into consideration in designing the current study:

- In view of the variability among studies with regard to operationalising criteria for the diagnosis of SLI, participant selection criteria had to be considered carefully.
- The linguistic deficits which are characteristic of SLI may impact on speech tasks, thus the linguistic complexity of tasks had to be considered carefully.
- Speech sound difficulties in adolescents with SLI are likely to involve a motor component. Motor speech disorders exist on a continuum, and it is likely that individuals with SLI who do have difficulties with motor speech, will present with a very mild impairment. Thus an assessment of speech in these individuals

had to be sensitive to subtle deficits. Such an assessment should probably include not only a right/wrong distinction of speech production, but also an analysis of the types of errors.

- It is apparent that children with SLI and DPD who have motor deficits can usually perform simple movements, but break down when required to integrate a number of movements into a sequence. The assessment therefore had to include integrated movements and longer stimuli.
- Motor deficits in individuals with SLI appear to be more apparent under timed conditions, thus the assessment should include at least one component which is timed.
- The SLI population is heterogeneous, thus the study should not report only on group trends, but also present individual results to identify variation within the group.
- The heterogeneity of the SLI population suggests that in order to derive meaningful results from research, it is preferable to investigate subtypes. Hence this study has elected to study persistent SLI.
- Linguistic deficits in particular areas appear to be closely related to speech output deficits. The study should therefore include an evaluation of linguistic ability in different areas (receptive and expressive language; morphosyntax and semantics) in order to establish links between speech ability and different aspects of linguistic ability.
- Individuals with SLI may be able to cope with simple speech tasks, but a reduced operating range may only be detected when task complexity increases. Tasks should therefore be designed to stress the speech system.
- Since processing limitations are hypothesized to underlie the deficits seen in SLI, it was felt to be important to include resource-intensive measures in order to tax the processing abilities of the participants.
- Factors such as automaticity and efficiency impact on resource allocation, thus it is necessary to evaluate these factors when analyzing task performance.

- Certain risk factors may pertain both to SLI and DPD, including genetic and neurodevelopmental factors and otitis media with effusion. Should the study find speech deficits in adolescents with SLI, these factors should be investigated to determine if individuals with persistent SLI and speech deficits show a particular risk profile.

3.6 Summary and Conclusions

From the above discussion it is apparent that SLI is not specific to language, but that it also involves nonverbal and motoric deficits which could contribute to speech deficits in this population. SLI is a heterogeneous disorder hence it is important to document communicative abilities in a number of subtypes in order to obtain accurate descriptions of these subtypes. The current study thus focuses on persistent SLI. Thus far there has been little research into subtypes of SLI with concomitant speech difficulties, which is one of the motivations for the current study.

Understanding the nature of SLI in terms of explanatory theories and the origins of the disorder is crucial for both researchers and clinicians working with this disorder, who ultimately want to provide the best services possible for individuals with this disorder. From the above discussion it appears likely that SLI is linked to processing limitations and that the characteristic language and memory deficits seen in this disorder may be related to a limited functional capacity of the language processing system. Resource allocation would therefore be a crucial component of language processing system, where any deficit which acts as a drain on resources may impact on processing speed and efficiency. This study hypothesized that speech production in adolescents with SLI is less automatic than in typically developing peers, thus requiring more resources. A threshold effect is proposed, whereby speech production and motoric factors interact with other linguistic and memory deficits to produce inefficient and slower processing.

The etiology of SLI is thought to be multifactorial, with the possibility that different subtypes may be related to different risk factors. Risk factors particular to persistent SLI have not been investigated, nor have risk factors specific to individuals

with SLI and speech production deficits been investigated. A number of risk factors are related to SLI. For the purposes of this study it is apparent that genetic, attentional, and early history factors, as well as otitis media with effusion are risk factors which should be investigated in adolescents with SLI.

The current study therefore aimed to extend the description of SLI, particularly speech production in persistent SLI, within a resource allocation framework; while also investigating causation in adolescents with this disorder.

4 Speech Development and Disorders in Adolescents with Specific Language Impairment

As SLPs are increasingly recognizing that older children with language and learning difficulties also benefit from intervention, it is important to extend our knowledge regarding the characteristics of adolescents with SLI. In this chapter the focus is on speech production in the adolescent with SLI. Firstly, the persistence of SLI will be discussed. Secondly, speech development into adolescence will be described. Thirdly, speech disorders in adolescence will be discussed, followed by a discussion of speech disorders specifically in adolescents with SLI. Thereafter interactions among speech, language and memory will be considered, followed by a discussion of the implications of speech disorders in adolescents with SLI. Finally, methodological considerations arising from points raised in this chapter will be summarised.

4.1 Persistence of SLI

Few studies have examined the deficits exhibited by adolescents or adults with SLI. There is thus a need to describe the changing characteristics of individuals with SLI as they mature by considering the language demands of adolescence as well as the persistence of SLI.

Language development beyond the preschool years is gradual and protracted, extending into, and even beyond adolescence (Berman, 2004; Nippold, 2004). Later language development is dependent on the child's cognitive readiness to advance to higher levels of thought, which only occurs around age 11-12 years, with the emergence of Piaget's stage of formal operational reasoning (Nippold, 2004). It is only during adolescence that children truly become capable of coping with the cognitive load involved in the simultaneous execution of different tasks (Berman, 2004), and the execution of tasks is progressively less influenced by the cognitive overload related to online processing of linguistic output. This is a significant point to consider for adolescents with SLI, who may have processing limitations and thus be unable to cope with these increasing cognitive demands. From a clinical

perspective, therapy should address the adolescent's ability to cope with the simultaneous execution of tasks, for example, during discourse. Speech is one of these tasks which must be executed while simultaneously processing other language and cognitive demands. Thus the impact of speech deficits on language processing during therapy tasks should be considered.

Later language development does not involve the accumulation of new linguistic forms. Rather, previously acquired forms evolve to acquire new functions, and old functions are expressed by an increasing diversity of linguistic forms (Tolchinsky, 2004). During adolescence, syntactic development continues in terms of increased utterance length, and increasingly frequent use of particular forms, such as relative clauses and modal auxiliaries; and variants of forms, such as center-embedded relative clauses (Scott, 2004). Semantic development is characterized by growth in the literate lexicon[21], abstract vocabulary and figurative language, while pragmatic abilities are developed through more extensive opportunities for socialization (Nippold, 2004). Metalinguistic strategies improve gradually, contributing in part to the ongoing cyclical relationship between literacy and later language development (Nippold, 2004). Development in all these areas may be affected in adolescents with SLI, who have to deal with the increased processing load accompanying later language development in the presence of deficits in one or more of the above areas (as discussed in Chapter 3).

For many children with SLI, the disorder persists into adolescence and adulthood. Some affected children may never reach fully adult-like competence (Rice, 2004). Stothard, Snowling, Bishop, Chipchase and Kaplan (1998, p.407) report that "…the consensus is that between about 50-90% of (affected) children continue to exhibit language difficulties through childhood, and many go on to have reading difficulties". It would appear that when children present with receptive as well as expressive language deficits, the disorder is likely to persist into the school-age years and beyond (Leonard, 1998; Law, Boyle, Harris, Harkness & Nye, 2000).

[21] A literate lexicon can be defined as a mental dictionary of complex and low frequency words, coexisting in an elaborate semantic network (Nippold, 2004).

Scott (2004) reported that school-age children with SLI (even at ages 11-12 years) will retain their core morphosyntactic deficit, which will now be manifested in written as well as oral language. In a longitudinal study of children with SLI, Stothard et al (1998) report that by age 15 years, this group presented with a wide range of verbal and nonverbal deficits.

Language plays a large role in a child's educational development, as well as social and behavioural adjustment. It is therefore not surprising that several studies have indicated that children with persistent SLI are at risk, not only in terms of verbal language, but also with regard to reading, spelling and other educational outcomes, as well as social, emotional and behavioural adjustment (Rice, Sell & Hadley, 1991; Catts, 1993; Redmond & Rice, 1998; Davison & Howlin, 1997; Benasich & Spitz, 1999; Law et al, 2000; Clegg, Hollis, Mawhood & Rutter, 2005). Longitudinal studies have demonstrated that a large number of children with a preschool history of SLI have later written language disorders involving reading and spelling (Stothard et al, 1998; Catts, Fey, Tomblin & Zhang, 2002). In particular, Catts et al (2002) found that the severity of the language disorder affected reading achievement. It should be noted that some of the language impaired children in these follow-up studies did not have reading difficulties, and that children with isolated expressive phonology deficits presented with good outcomes. Similar findings were reported by Catts (1993). Thus not all adolescents with persistent SLI will have negative academic and social outcomes. Good speech production can contribute to academic and social success, thus clinicians working with adolescents with SLI should consider whether these clients present with adequate speech output.

Clinicians should also aim to minimize the long-term effects of SLI. Several studies on adults with a history of SLI, or adults with a family history of SLI have confirmed that language deficits can persist into adulthood (Gopnik & Crago, 1991; Tomblin, Freese & Records, 1992; Clegg, Hollis, Mawhood & Rutter, 2005). Adults with SLI have been reported to demonstrate continued grammatical errors and word-finding problems (Hall & Tomblin, 1978, in Tomblin, Freese & Records, 1992); weaknesses of information processing and phonological performance (Tomblin et al,

1992); impairment of cognitive skills, including theory of mind and literacy; and impaired social adaptation, with regard to employment, independent living, marriage and friendships (Clegg et al, 2005). The fact that phonological performance can still be impaired in adulthood, suggests that the SLP working with adolescents may need to focus on this area.

SLI may therefore persist, potentially with wide-ranging effects on an individual's academic and social functioning. Two implications are important for the current study. Firstly, since the linguistic deficits persist beyond the early school years, it is probable that nonlinguistic deficits, including speech production deficits may also persist. Secondly, language development during adolescence brings increased processing demands in terms of managing the cognitive load related to comprehending and producing more sophisticated language forms and functions. There are therefore more demands on the available resources for language processing. If one of the resources, such as speech production is impaired, performance on language tasks may be affected.

4.2 Speech Development in Adolescence

Adolescence represents a mid-point between childhood and adulthood, involving a number of biological changes, referred to as "puberty" (Walsh & Smith, 2002). Changes that occur during puberty include marked cognitive development, physical growth, changes in body composition and full maturation of the circulatory, respiratory and reproductive subsystems (Steinberg, 1996). Early adolescence is marked by rapid physical growth and maturation, whereas late adolescence marks a period of refinement toward maturity (Steinberg, 1996). However, the physical changes occurring during puberty should not be seen in isolation.

Cognitive changes also occur during adolescence. Walsh and Smith (2002) propose that central factors related to cognitive and language factors may play a significant role in prolonging the development of speech motor processes. Similarly, the development of phonology is closely linked to cognitive and motor processes, as

well as the simultaneous acquisition of semantic, morphosyntactic and pragmatic skills (Bauman-Waengler, 1994).

In the sections below, speech development in adolescence will be discussed in terms of development in the areas of auditory perception, phonology, physical maturation, motor speech production, and neurological maturation. Thereafter factors which may influence speech production within an information processing model will be described. Table 4-1 provides a summary of factors related to speech production during adolescence (particularly early adolescence) in children with typical language development, and those with SLI.

Table 4-1: Summary of factors related to speech production in early adolescence.

Factor	Typical Language Development	SLI
Auditory Perception	Continuous speech is still processed more slowly than adults; ability to use semantic information to compensate for poor perception is still developing (Vihman, 1988a).	The impact of rapid temporal processing deficits is not known. Linguistic deficits may impact on redundancy of messages.
Phonological Development	All speech sounds acquired (Yavaş, 1998). Fluency in planning and production of complex sound sequences continues to develop (Vihman, 1988b).	Possible residual speech errors if history of phonological disorder (Lewis & Freebairn, 1992)
Physical Development	Continued craniofacial and oral growth. Growth of respiratory and laryngeal structures may only be completed in late adolescence (Kent, 1999).	
Motor Speech Development	Protracted development in terms of movement duration, velocity, displacement and variability in movements. Speech segments decrease in duration with age (Walsh & Smith, 2002).	Potential impact of motor deficits in SLI on speech production is not known.
Neurological Development	Full developmental maturity not yet attained (Brown & Minns, 1999). Cortical development continues (Paus et al, 1999; Walsh & Smith, 2002). Neural systems governing language functions still undergo significant development until 15-16 years (Walsh & Smith, 2002).	Possible hypoactivity in areas related to attention, memory and language processing (Elllis Weismer, Plante, Jones & Tomblin, 2005).

4.2.1 Auditory Perceptual Development

Auditory perceptual abilities continue to develop into adolescence. School-age children appear to process continuous speech in an adult-like way, as they use context to aid their interpretation of the acoustic signal (Vihman, 1988a). However, there are still some differences compared to adult auditory perception. The child's recognition of isolated words under quiet listening conditions continues to improve up to age 10 years; they still process continuous speech more slowly than adults; and their ability to use semantic information to help interpret speech under difficult listening conditions continues to develop up to age 15 years (Vihman, 1988a). In children with SLI, where rapid temporal processing and linguistic knowledge are impaired (see Chapter 3), auditory perceptual development may be more protracted.

4.2.2 Phonological Development

It is difficult to pinpoint exactly when speech sound development starts and ends (Weiss, Gordon & Lillywhite, 1987). While much has been written about the onset of speech development, less is known about the completion of this developmental process.

Phonological development in terms of the acquisition of speech sounds is largely complete by the end of the preschool years. By age 4 years, articulation closely resembles that of adults (Vihman, 1988b), and intelligibility reaches 100%, with occasional exceptions (Weiss, Gordon & Lillywhite, 1987). Certain fricatives and affricates may only be established late, with consonant clusters also proving difficult (Yavaş, 1998). Between the ages of five and eight years, the phonetic inventory is completed and children learn allophonic variations; while morphophonemic development[22] begins, and continues to develop into late adolescence (Bauman-Waengler, 1994; Yavaş, 1998).

[22] Morphophonemic development refers to the acquisition of a system of rules for the combination of morphemes (Yavaş, 1998), such as vowel alternations (e.g. sane/sanity); the plural rule; and stress alterations regarding compounds and noun phrases (e.g sunshine versus sun shine).

After the age of eight years, metaphonological skills[23] and phonological reorganization develop in close relationship with reading and writing (Vihman, 1988b; Bauman-Waengler, 1994). Through their exposure to literate forms, children develop knowledge of vowel alterations; spelling influences perception and production; and lexical organization undergoes changes (Vihman, 1988b). Children who have difficulties with written language (which includes many children with SLI), may be disadvantaged in this regard.

The development of suprasegmentals (prosodic elements) continues into adolescence, particularly where suprasegmentals serve a grammatic function (Bauman-Waengler, 1994). Prosodic development may thus be influenced by impairments in grammatical knowledge.

In terms of temporal coordination, studies of timing problems posed by the production of consonants in clusters and in long words have shown that fluency in planning and production of complex sound sequences continues to develop into adolescence, even though school-aged children are able to produce acceptably adult-like speech (Vihman, 1988b).

If, as is commonly accepted, children with SLI have delayed phonological development during the preschool years, it is not unreasonable to predict that they may also have delayed development in the later stages of phonological development, and that young adolescents with SLI would still have difficulties with temporal coordination, morphophonemic knowledge and metaphonological development.

4.2.3 Physical Development Related to Speech Production

Speech develops not only because of cognitive and linguistic development, but also because of the maturation of the vocal tract and the neurophysiologic control of vocal tract musculature (Caruso & Strand, 1999). There are significant changes between the structures involved in speech production in infants versus adults (Callan, Kent, Guenther & Vorperian, 2000) and speech motor control in children must thus be adapted to the changing nature of the physiologic system of speech (Kent, 1999).

[23] Metaphonological skills involve a child's conscious awareness of sounds within language, including awareness of how sounds are combined to form words (Bauman-Waengler, 1994).

Speech is therefore acquired and refined during a period when the respiratory, laryngeal and supralaryngeal systems are undergoing growth and development, which includes: increases in size, remodelling in the shape of individual structures, adjustment in the positional relationships between structures, changes in histology, alterations in biomechanical properties, and adaptations in neural innervation (Kent, 1999). Anatomical structures continue to change well into adolescence, which would have an impact on speech development. At present it is not known how the marked cognitive and physical changes after age 12 years affect speech production during adolescence, or when the developmental process is essentially complete (Walsh & Smith, 2002).

The following physical changes are pertinent to this study (Kent, 1999):

Vocal Tract and Bony Structures: Physical development of the craniofacial and oral structures is only fully complete by late adolescence. A growth spurt occurs in the lower face between the ages of 7-10 years, followed by rapid growth of the tongue and lips between 9-13 years. By the age of 12 years, the vocal tract is mature in girls, but growth of the lips, jaw and tongue continues until about 18 years in boys. By age 14 years all the permanent teeth, with the exception of the wisdom teeth have erupted. Lingual maturity is reached at approximately 15-16 years, which is also when the mandible reaches adult size in girls. By age 16 years adult proportions are essentially developed, although some structures (such as the mandible) continue to grow in boys.

Respiration*:* Functional maturity of the respiratory system is attained by age 10 years. After the age of 12 years, lung capacity continues to increase, particularly in boys, and 15 years can be regarded as the age of growth completion in the respiratory system.

Phonation: By 12 years, vocal folds assume an adult-like histology. Adult morphology of vocal folds is achieved by 16 years. In boys, adolescent voice changes begin around age 12 years, and their vocal folds may continue to increase in length until 18 years.

Children thus have to accomplish speech goals in the face of alterations in associated sensory cues during development as a result of the ongoing changes in size, shape and muscle innervation patterns of the articulators (Callan, Kent, Guenther & Vorperian, 2000). The parameters of the systems to be controlled are changing constantly in children hence highly stable, centrally patterned articulatory movements would not be adaptive for children. In children there may thus be bottom-up requirements for adaptation in central control networks. While children with SLI are not expected to differ from normal peers in terms of physical development, their ability to manage this challenge may be less effective than that of their peers.

4.2.4 Motor Speech Development

Far from speech development being completed before the onset of puberty, the continued anatomical, physiological and neurological development during puberty could influence how articulators are controlled for speech production, as movement solutions need to adapt to these developmental changes (Walsh & Smith, 2002). However, apart from the Walsh and Smith study, there have been few studies of articulatory kinematics in children older than 12 years. Hence it is not clear how the cognitive and physical changes which occur during puberty could affect speech production during adolescence, or when the developmental process is complete. At present there is no widely accepted, comprehensive model for the acquisition of speech motor processes (Walsh & Smith, 2002), and while much is known about speech production in children up to the age of 10 years, and adults, much less is known about changes in speech development during adolescence.

Kinematic studies of speech production during development have indicated that significant changes in speech motor control occur during adolescence. Normal adolescents have been found to have more variability in their speech motor behaviours than normal adults (Walsh & Smith, 2002), suggesting that in this population there may be a greater need to compensate for such variability. Adolescents also have longer movement durations, lower velocities and smaller

displacements of the upper and lower lip and jaw than adults (Walsh & Smith, 2002). Their study thus provides evidence that speech motor processes follow a protracted developmental time course, extending beyond 16 years.

Adolescents may be using more variable movement strategies to achieve perceptual goals, as variability may allow the developing speech motor system flexibility to compensate for ongoing changes in peripheral biomechanics and in central networks mediating speech production (Thelen & Smith, 1998, in Walsh & Smith, 2002).

Other studies have reported similar results to that of Walsh and Smith (2002). In a study on visuomotor control of the oral-facial system across the lifespan, Ballard, Robin, Woodworth and Zimba (2001) found that the performance of children aged 8.2 to 17.0 years was poorer than that of young adults. Performance improved from 8 years of age, but only levelled at about 15-16 years, indicating that control of the articulators is not fully established until adolescence. In a study evaluating stability of movement sequences, Smith and Goffman (1998) found that children have large movement ranges in their speech, relative to the size of their oral structures. They attributed children's large-amplitude, low-velocity movement styles to different control processes, compared to adults.

An EMG study by Wohlert and Smith (2002) found that 12-year old children used varying combinations of muscle activity to achieve phonetic goals, and that even at age 12 years these children were not adult-like in their performance. Wohlert and Smith proposed that the more variable trajectories for children's speech movements should be interpreted as reflecting differences in active processes involved in the planning and execution of speech movements, rather than merely the result of biomechanical differences between developing and mature speech motor systems. As such, variability in performance may fluctuate within a child, depending on factors such as rate of physical and linguistic change. Language impairment, such as SLI, may thus affect variability in performance.

By twelve years, children are speaking at 90% of adult rate, but then reach a plateau, with 16-year old children still speaking slower than adults (Walsh & Smith,

2002). Walsh and Smith propose that central factors, perhaps related to speed of cognitive and language factors may constrain speaking rate. Adolescents appear to sacrifice timing consistency in order to reach a faster/ adultlike rate (although they cannot sustain this rate). Walsh and Smith (2002) therefore suggested that these adolescents were using a time-accuracy trade-off, using a lower velocity/longer duration strategy to allow additional time for both language processing and the organization and issuing of motor commands.

Motor speech development therefore continues during adolescence. Adolescents with SLI who also have motor deficits, may have an even more protracted development in this area than normal adolescents, and may possibly never reach adult levels of competence. If, as Walsh and Smith (2002) hypothesized, central factors, such as cognitive and language processes play a significant role in prolonging the development of speech motor processes, children with SLI may be at-risk for an even more protracted developmental period.

4.2.5 Neurological Development

Neural subsystems play a critical role in speech production, simultaneously coordinating the respiratory, laryngeal and articulatory subsystems, while integrating semantic, syntactic and phonological aspects of language during speech production (Walsh & Smith, 2002). However, the central and peripheral nervous systems continue to mature throughout development (Caruso & Strand, 1999; Paus et al, 1999) and the brain does not reach developmental maturity until well into adolescence (Brown & Minns, 1999), which thus has implications for language and motor speech development.

Neural systems mediating language functions continue to mature into adolescence. While event-related potentials demonstrate early maturation of semantic processing, mature grammatical processing is not present until adolescence (Smith & Goffman, 1998). Nittrouer (1993, in Smith & Goffman, 1998) suggested that the maturation of articulatory sequences is nonuniform and dependent on the linguistic complexity of the utterance, as well as the specific articulator and the

phonetic composition. Thus Smith and Goffman suggest top-down linguistic and phonological requirements for motor system flexibility as children mature, into the teen years.

The development of neural pathways for speech motor control should also be considered. Developmental changes in motor control may be related to neuromotor maturation, which results in increased speed and accuracy, and decreased variability in movement (Ballard, Robin, Woodworth & Zimba, 2001). There is evidence from neuro-imaging studies that cortical development, particularly the fibre tracts thought to support motor and speech functions, has an extended and variable course of development into mid-adolescence (Paus et al, 1999; Walsh & Smith, 2002), while event-related potentials (ERPs) to auditory and visual stimuli provide evidence that language-related neural systems show significant development until 15-16 years (Walsh & Smith, 2002). The protracted development of neural pathways would affect the speed and efficiency of transmission among the multiple brain regions required for the integration of cognitive and motor tasks during speech production (Walsh & Smith, 2002).

Of relevance to the current study is the fact that the speech motor area reaches maturity in advance of the frontal region (Broca's area) which is thought to assist in organizing skilled movements for speech (Kent, 1999), which may explain why young children can perform speech movements in isolation, but have difficulty with rapid or complex speech sound sequences.

Recent advances in neuroimaging have provided evidence of functional neurological differences between individuals with SLI and those with normal language development. For example, an fMRI (functional magnetic resonance imaging) study on adolescents with SLI found significant hypoactivity in areas related to attention, memory and language processing (Elllis Weismer, Plante, Jones & Tomblin, 2005).

Neurological development is therefore still continuing during adolescence, which has implications for speech motor control processes. Children with SLI are known to demonstrate functional neurological differences from normal children when

performing language tasks. Some children with SLI, who have motor deficits, may be regarded as having MND, which is reportedly more prevalent just before the beginning of puberty (Hadders-Algra & Lindahl, 1999). Young adolescents with SLI may therefore have speech difficulties related to immaturity, and possibly dysfunction, of the neurological system.

4.2.6 Factors Affecting Speech Production during Development

In this study, the focus was not on the initial development of phonology and the production of speech sounds (which are well-documented), but on speech development in older children, where the development is reaching completion.

Sensorimotor processes (motor planning, programming and execution) systematically interact with each other, and thus are fundamental to a robust speech mechanism. Thus not every error during planning, programming or execution will result in a perceptible speech error, as errors made at one level, can be reduced by modifications at other levels (Caruso & Strand, 1999). This concept of redundancy ensures that normal-sounding speech can be produced even when processing at one or more levels is not perfect.

The concept of redundancy is an important one to consider in children with SLI, and/or children with a history of phonological disorder. On the surface these children may be producing normal-sounding speech, which does not guarantee that their speech production systems are intact. It is possible that these children are heavily reliant on redundancy and feedforward and feedback information to produce adequate speech. As a result, speech production may be a more effortful task for these children.

It is important to consider factors impacting on redundancy of the speech system, as well as factors influencing the speech motor processes underlying speech development in children which have not yet been discussed. These factors include: auditory feedback, interactions between language and motor skills during acquisition, automaticity and resource allocation, contextual sensitivity and rate of movement.

Auditory Feedback

Similar to models of information processing, feedforward and feedback information are integral to movement control (van der Merwe, 1997). During speech production, proprioceptive, tactile and auditory feedback information is provided to the brain. It is assumed that feedback is more important to children than adults (Kent, 1999), where feedback (particularly auditory feedback) would be essential to achieve or maintain correct speech production in the face of morphological changes to the articulators during development (Callan, Kent, Guenther & Vorperian, 2000).

It has not yet been established clearly what the relationship is between the auditory perceptual deficits documented in children with SLI, and speech production. Children with SLI have difficulties in perceiving or discriminating speech, particularly consonants (Gillam, Cowan & Marler, 1998) and require more time to process sensory information across modalities (Ellis Weismer & Hesketh, 1996). It can only be assumed that these deficits play some role in the development of speech. The fact that speech abilities of older children with SLI are not noticeably affected does not necessarily imply that their auditory perceptual deficits are not impacting on speech production. The concept of redundancy would suggest that the children can compensate for such weaknesses. However, if one component of the system (auditory feedback) is limited, the redundancy of the system is reduced, rendering it more vulnerable to breakdown when there is competition for resources. This is an important factor to consider in the treatment of children with a history of auditory perceptual deficits.

Language and Motor Skills Interact During Acquisition

Motor and linguistic skills are developing simultaneously, therefore motor impairment at any level will affect the ongoing acquisition of phonology and other linguistic skills (Caruso & Strand, 1999). Models of language and models of speech have largely developed independently of each other, with predictable effects on assessment and intervention for speech and language disorders. However, as Caruso and Strand (1999) emphasized, any assessment of communication must account for

the effects of varying phonetic, linguistic and motor requirements on task performance.

Kent (1999) suggested that the development of motor skill can be characterized as motor sequences of increased speed of performance, reduced variability across tokens, and increased anticipation across the sequence. However, he pointed out that these principles can be affected by other factors that arise during development. For example, a pattern of increasing speed of performance may be interrupted by aspects of language learning, and a phonetic sequence may actually be produced more slowly as it is incorporated into early words. This interaction would suggest that linguistic factors can impact on motor speech production during development. Kent's suggestions are similar to those of Caruso and Strand (1999), who suggested that motor skill may be degraded as linguistic demands, and presumably resource demands, are increased. As children with SLI have an impaired linguistic system, they may be even more vulnerable to disruptions of speech motor execution.

Certain subtypes of speech disorder may be particularly vulnerable to interactions of language and motor skills. For example, Strand and McCauley (1999) proposed that several types of phonological impairment have a motoric component in addition to a linguistic component. It is likely that residual motor deficits would remain even once the child is capable of producing acoustically acceptable output, and has largely resolved the linguistic component of the speech deficit. However, both the motor and linguistic components may be functioning at less than optimal levels. Therefore, should demands for resources increase, speech production may either break down, or make a greater demand on available resources. This is an important factor to consider in discharging children from therapy. Performance on speech and language tasks should be assessed under resource-intensive conditions before an individual is considered ready to stop receiving intervention.

Automaticity and Resource Allocation

As with any new movement, children initially use very controlled processing to manage the complex, rapid sequences of movements required for speech (Caruso &

Strand, 1999), but over time these movements become well practiced or habituated, that is, automatic motor processing is achieved (Strand & McCauley, 1999) which does not demand attentional resources (Field, 2004). These more practiced movements require less conscious processing. In the area of language development, it has been shown that limited processing capacity influences language performance. However, little is known about the effects of limited processing capacity on speech motor control during development.

Certain combinations of sounds may pose higher demands to the linguistic-symbolic planning of an utterance, thus requiring more conscious processing, while also being more motorically difficult to produce (van der Merwe, 1997). Similarly, Duffy (1995) suggested that it is likely that the allocation of resources for motor speech programming and control among the high, low and intermediate levels of the motor system may vary as a function of task complexity. Lower level functions would involve reflexive-like movements, which are stereotyped and do not require conscious effort. Higher level regulation of movement is slower and less automatic. Duffy suggests that higher levels of the system are more involved when the speech task is motorically complex or novel. It is presumed that higher level processes would demand more resources. In mature speakers, it is likely that many aspects of speech movements are preprogrammed. The same may not be true of children, as they have not had the same amount of practice and have to adjust to a constantly changing biomechanical system. Children (and adolescents) may therefore need to allocate more resources to speech production than adults.

In terms of automaticity, children may therefore be more reliant on controlled processing for speech. It could be presumed that adolescents are in the process of developing higher levels of automaticity in speech production, particularly as biomechanical maturation of the vocal tract is largely complete by early adolescence. However, when producing novel words, particularly nonsense words, higher levels of controlled processing may be required, as an individual may not have stored templates to facilitate processing.

Resource allocation may impact on a child's ability to manage speech motor control processes in order to produce speech, particularly when other processing demands, such as linguistic complexity, increase. Complex speech tasks, requiring more controlled processing, may be competing for resources required for linguistic processing, possibly resulting in a breakdown of either speech or linguistic processing.

Contextual Sensitivity

Van der Merwe (1997) hypothesized that contextual factors affected the dynamics of motor control as differences in the level of activity of certain neural structures have been observed during different motor tasks. In particular, it appears that precise, unfamiliar movements require greater implementation of sensory input than well-learned movements, requiring greater involvement of sensory areas. Thus more complex control strategies may be required in certain contexts than others.

Although the contextual factors thought to influence speech sensorimotor control are still hypothetical, van der Merwe (1997) identified the following potential contextual factors: Sound or phonological structure; voluntary versus involuntary (automatic) speech; motor complexity of the utterance; length of utterance; rate of speech; and familiar versus unfamiliar utterances. The latter factor is of particular importance when children are requested to repeat utterances such as nonwords, which may require more complex control processes than real words. It is also apparent that words with complex phonological structure, particularly if these sound sequences are motorically complex, may demand more complex control strategies. Within a resource allocation framework, it can be assumed that such tasks would be more demanding of resources.

Rate of Movement

One of the most robust findings in human neuromotor control is the consistently identified "trade-off" between speed and accuracy of movement. Thus as motor tasks or contexts become more complex, rate of speech is reduced. Ballard, Robin,

Woodworth and Zimba (2001) reported that control of the motor system develops gradually in childhood, and deteriorates with aging. Thus children and older adults tend to demonstrate reduced velocity of movement and greater variability, resulting in a less accurate performance than that of young adults.

With regard to rate of speech, Walsh and Smith (2002) found that 16-year old adolescents still had significantly slower rates of speech than young adults, and that there was no significant increase in the 12-16 year period. Walsh and Smith proposed that these speaking rate growth curves point to more central factors, perhaps related to speed of cognitive or language processes. For example, it is plausible that the lower velocity/longer duration strategy adopted by adolescents allows additional time for language processing, as well as for organizing and issuing motor commands. Individuals with SLI use a slower rate of speech (Tomblin, Freese & Records, 1992; Flipsen 2002), possibly because of motoric factors, but perhaps also to assist language processing. As will be discussed in 4.4.2., the impact of a slow rate of speech on short term memory and other aspects of processing has to be considered.

4.3 Speech Disorders in Adolescents with SLI

Children with SLI often have abnormal speech development. In a review of literature, Foy and Mann (2001) reported that children with SLI have been found to have less complex babbling, less productive use of complex syllables and consonants, fewer vocalizations and smaller phonetic inventories compared to controls. Results point to delayed, rather than deviant phonological development.

Children with SLI appear to acquire phonemes and distinctive features in the same order as typically developing peers, although the development may be protracted (Leonard, 1998) and children with SLI may have smaller phoneme repertoires than chronological age peers (Craig, 1996). Similarly, children with SLI do not differ markedly from peers with regard to the use of phonological processes, although the phonological processes appear to persist for a longer period (Dodd's delayed phonological acquisition group). For example, Fee (1995) found that some

adults with language disorders still showed evidence of final consonant deletion and word final consonant cluster reduction.

Prevalence studies generally find that there is an apparent decrease in the prevalence of articulation/phonology disorders with an increase in age. Speech problems may therefore appear less persistent than language problems. For example, Felsenfeld (2002) reported a decrease from 14% at ages 3-4 years, to 3.8% at 6 years. Such a decrease in prevalence has been interpreted to indicate that many speech disorders resolve.

However, this apparent decline in prevalence may be related to methodological issues and the definition of phonological disorder. While preschool children with phonological disorders are readily identifiable using traditional phonological tests and speech samples (Lewis & Freebairn, 1992), residual effects in adolescence and adulthood are less easily recognized, thus leading to the assumption that these disorders are fully resolved. Stackhouse (2002) has suggested that the identification of persisting speech and language difficulties is not straightforward, since not all children have obvious spoken difficulties throughout their school life. As Lewis and Freebairn (1992) pointed out, follow-up studies of individuals with a history of phonological disorder, have tended to focus on linguistic, educational, and social outcomes, rather than evaluating speech.

There is substantial evidence that there may be subtle residual effects of earlier articulation deficits in adolescents and adults (Lewis & Freebairn, 1992; Shriberg, Austin, Lewis, McSweeny & Wilson, 1997). In a 14-year longitudinal study, Johnson et al (1999) reported that by age 18-20 years, many of their participants with a history of speech and/or language impairment still presented with mild articulation problems. These articulation problems were described as: minor distortions or errors not impairing intelligibility; deterioration in speech precision with increased rate or linguistic complexity; and minor distortions and imprecision, which sounds very much like Shriberg's Residual Errors group on the SDCS. Lewis and Freebairn (1992) also reported that adolescents and adults with a history of preschool phonology disorder were less proficient than normal counterparts in rapidly

sequencing syllables, producing difficult phoneme combinations or producing novel sound sequences.

In studies comparing language impaired children to reading impaired and normal children, Kamhi and Catts (1986) and Kamhi, Catts, Mauer, Apel and Gentry (1988) found that the language impaired group performed worse than the normal group on word and sentence repetition tasks. Kamhi et al (1988) reported that multisyllabic nonsense words were much more difficult for the language impaired group than any other nonsense word stimuli. They concluded that impaired phonological encoding could not explain this finding, but that the most plausible explanation was that the language impaired children were less proficient in planning complex phonological sequences. A crucial finding of their study (as well as that of Catts [1986]) was that language impaired children aged 6-8 years did not necessarily have difficulty with the articulation of individual speech segments, but that it was the complexity of the phonological structure of words that influenced speech performance. These children would therefore resemble Dodd's (1995b) inconsistent group.

Speaking rate appears to be an important defining feature of older individuals with SLI. Tomblin, Freese and Records (1992) found a reduced speaking rate in adults with a history of SLI as children. Tomblin et al suggest that information processing limitations may continue to impede language usage in young adults, even when language learning has probably reached its peak. In their study, speaking rate was part of a four-variable model[24] found to discriminate reliably between adults with SLI and normal-language controls in both a face-to-face and telephone assessment.

In a follow-up study of children with speech delay at nine years and 12-16 years, Flipsen (2002) reported that these children had a significantly slower articulation rate in an embedded words task (although not in conversational speech). He concluded that children with speech delay of unknown origin whose speech does not normalize may have relative speech-motor difficulties, as well as deficits in language formulation, although the slower articulation rate could also reflect compensation for

[24] The four-variable model determined by stepwise discriminant analysis of predictor variables included the Modified Token Test, Speaking Rate, Written Spelling and Confrontation Naming Speed (Tomblin, Freese & Records, 1992).

the continued speech sound errors. Such compensation in terms of slower articulation rate could reflect a time-accuracy trade-off, where in the vicinity of problematic sounds, the participants slowed their rate to increase accuracy or improve intelligibility (Flipsen, 2002).

As discussed above, many children with SLI present with reading difficulties into adolescence and adulthood. Studies on less skilled readers have found that they have inaccurate and inconsistent production of words with clusters and phonologically demanding phoneme sequences such as long words, low-frequency words, tongue twisters and pseudowords (Dietrich & Brady, 2001). These findings may be applicable to some children with SLI, who may have been included in the group of less skilled readers.

Children with SLI frequently present with fluency and rate problems, which are typically related to the complexity of a discourse task. Fluency in relation to SLI can be defined as how smoothly discourse is produced (Miranda, McCabe & Bliss, 1998). Fluency problems may be tied to difficulties in word-finding, sentence formulation, or a reduced ability to plan, monitor and repair utterances, although the precise source is not clear (Leonard, 1998; Miranda, McCabe & Bliss, 1998). Children with SLI use more frequent pauses and use fewer words per minute (Miller, 1996), while also exhibiting dysfluencies (reformulations, repetitions and discontinuations) long past age 6 years, when such dysfluencies typically decrease in normally developing individuals (German & Simon, 1991).

In summary, older children with a history of language impairment and/or speech delay may present with minor distortions, inconsistent errors that are influenced by linguistic and phonological context, impaired sequencing, a reduced articulation rate, and typical dysfluencies. These speech difficulties could be attributed to speech-motor difficulties or difficulties with phonological encoding or planning. However, none of the above studies specifically investigated speech production in adolescents with SLI. The Flipsen (2002) and Lewis and Freebairn (1992) studies investigated children with only phonological disorders; Kamhi and Catts (1986) and Kamhi, Catts, Mauer, Apel and Gentry (1988) investigated younger language and reading impaired

children; while Johnson et al's (1999) study included a diverse group of communicatively impaired children, not only children with SLI.

The high co-occurrence of SLI and speech disorders and the persistence of speech disorders into adolescence, thus form the basis of the hypothesis of the current study: that adolescents with SLI have a high likelihood of having residual speech errors.

4.4 Interactions among Speech, Language and Memory

The potential impact of persisting speech difficulties in individuals with SLI has not been considered in any depth. However, there is compelling evidence for interactions among memory and language (the primary deficits in SLI), and speech. Hence, even if overt and consistent speech errors are not evident in the speech of individuals with SLI, subtle speech deficits may impact on their memory and language abilities.

Verbal communication is a complex construct, involving interactions among cognition, language, memory and speech. Little is known about the speech abilities of individuals with SLI, and more importantly, the interactions among language, memory and speech which may serve to facilitate or impede verbal communication. In particular, it is not known whether the degree or the nature of interactions between various levels of language (phonology, morphosyntax, semantics and pragmatics), and motor processing differ in typically developing and disordered children (Maner, Smith & Grayson, 2000). It is also not known how these interactive processes change over the lifespan.

In the sections below, potential interactions among language, short term and working memory and speech will be discussed within an information processing approach, with particular reference to adolescents with SLI. Finally, in view of potential interactions among language, memory and speech, the use of nonword repetition as a diagnostic measure for SLI will be evaluated.

4.4.1 Language and Speech

Language Influences Speech

Much has been written about the influences of syntactic and semantic complexity of utterances, on articulation and fluency. The cognitive-linguistic demands associated with a speech-language task could influence the performance of that task (e.g. Crary, 1993; Kleinow & Smith, 2000; Dromey & Benson, 2003). For example, misarticulations and speech fluency are influenced negatively by increased syntactic complexity (Enger, Hood & Shulman, 1988), semantic complexity (Haynes & Pindzola, 2004) and discourse demands (Owens, 2004).

With regard to articulation and semantics, research has shown that both normally developing and phonologically delayed children tend to have more misarticulations on verbs than nouns (Haynes & Pindzola, 2004), which certainly has implications for the many studies on verb morphology in preschoolers with SLI.

Fluency can be affected by higher levels of language formulation. Any increased demand in terms of task complexity or linguistic capacity increases the probability and rate of dysfluency in children who do not stutter (Tetnowski, 1998). When nonstuttering preschool children were grouped according to whether they were fluent or dysfluent, the fluent children had more complex expressive language skills (Enger, Hood & Shulman, 1988), suggesting an interaction between expressive ability and fluency. A study by Silverman and Ratner (1997 in Kleinow & Smith, 2000) found that increases in syntactic complexity resulted in a greater number of normal dysfluencies in the speech of both adolescents who do and do not stutter. During the production of narratives, children with language difficulties have a greater rate of mazing behaviours (false starts, pauses, repetitions, and revisions), which may be attributed to the communication demands of this complex task (MacLachlan & Chapman, 1988 in Owens, 2004).

There is evidence that speech motor performance deteriorates under conditions of increased linguistic demand, regardless of whether overt changes in articulation or fluency occur. For example, there is evidence linking increased utterance length demands and decreased motor performance (measured by disruptions to speech motor

stability) for normally fluent and stuttering individuals (Kleinow & Smith, 2000). Maner, Smith and Grayson (2000) also demonstrated that children displayed greater temporal and spatial variability in their speech movements as linguistic demands were increased, despite their ability to produce fluent and phonologically accurate speech. Dromey and Benson (2003) investigated the effects of concurrent motor, linguistic, and cognitive tasks on speech motor performance in normal, college-aged adults. They found that distractor tasks have a significant influence on speech motor performance, as measured on labial kinematic measures. Finally, studies of divided attention involving speech have indicated that speech production demands resources that might otherwise be used for a variety of tasks (Dromey & Benson, 2003).

The effects of increased linguistic demands may be even more noticeable in children and adolescents, whose language systems are still developing. Support for this theory was presented by Maner, Smith and Grayson (2000), who compared the performance of 5-year old children and adults on speech tasks of increasing utterance length and complexity. They found that children were more negatively affected by increased processing demands. Maner et al (2000) proposed that adults have more stable production systems at all levels and are thus less vulnerable to the effects of increasing processing demands. Maner et al found that their 5-year olds used less stable neural systems to achieve linguistic goals, despite their capability of producing the sentences without errors.

Within a limited capacity theory, the demands of language, cognition and motor processes must be met by a finite pool of resources. Dromey and Benson's (2003) findings led them to conclude that the balance of neural resources allocated to different processing tasks during communication may shift according to situational demands, and that the way speech movements are executed may be compromised when language processing demands increase. In children with communication disorders, the available resources may not be able meet the combined cognitive, linguistic and motor demands of communication. Thus, the presence of a communication disorder may limit the available resources in such a way as to make motor output less consistent (Dromey & Benson, 2003).

Speech Influences Language

Resource limitations related to speech development may preclude a child from demonstrating his/her full linguistic knowledge. Adams and Gathercole (2000) propose that performance limitations may constrain the degree of complexity that speech can achieve at any given point. In this view, language errors occur because the accumulated complexity of the sentence exceeds the child's current production resources. Adams and Gathercole suggest that this explanation may account for children's gradual progression to linguistic competence, as well as individual differences in the rate of this progression and inconsistencies within the same child at different times.

Speech production difficulties appear to be closely linked to expressive language deficits. For example, van Daal, Verhoeven and van Balkom (2004) found that speech production problems and low expressive language performance clustered together in about one third of their sample of 110 children with SLI, leading them to conclude that poor articulation skills may directly influence children's performance in word production, sentence repetition and narrative production.

It is possible that the difficulties SLI children encounter in the use of morphemes, may be related in part to speech difficulties. Grammatical morphemes of low phonetic substance[25] appear particularly difficult for children with SLI (Leonard, McGregor & Allen, 1992). Leonard et al report that children with SLI can use these phonetic forms in nonmorphophonemic contexts, and that the difficulty appears to lie in the combined effects of perceiving the form and treating it as a morpheme. If, as is proposed in this study, many children with SLI have subtle speech difficulties, it is possible that they can produce certain phonetic forms in undemanding contexts. However, when tasks become more demanding of resources, the subtle speech difficulties and impaired morphological knowledge may have an additive effect, resulting in impaired output.

[25] Morphemes of low phonetic substance are usually unstressed syllables or nonsyllabic consonant segments, characterized by shorter duration than adjacent morphemes, and often with lower fundamental frequency and amplitude (Leonard, 1998).

Speech difficulties may also affect vocabulary acquisition. In order to acquire a word, a child must link a particular sequence of sounds to a particular meaning, and must learn the articulatory movements needed to make these sounds (Stoel-Gammon, 1998). Particularly during the early stages of learning to talk, phonology influences lexical development, and there is some evidence that children with smaller vocabularies have limited phonetic inventories (Stoel-Gammon, 1998), although these studies can be criticized as results are only based on children learning English, and there is no data regarding frequency of input.

4.4.2 Memory and Speech

Memory Influences Speech

Short term phonological memory may serve as a speech output buffer (as was discussed in Chapter 2). Adams and Gathercole (1995) and Gathercole et al (2005) proposed that phonological working memory may serve to hold intended utterances during the formulation of output, until articulatory programs can be applied. They have suggested that the phonological memory may have more of a role as speech output buffer in children than adults. In adults, speech programming and maintenance of information in phonological memory would be more automatic and possibly output is achieved by direct activation of phonological representations stored in the lexicon (Bock, 1982 in Adams & Gathercole, 1995). In children, the planning and execution of articulatory gestures may not yet be automatic, and are thus more demanding of control processes. For example, Bock suggested that the automatic processing of speech output would be dependent on the development of grammatical and phonological encoding processes. In particular, Adams and Gathercole suggested that children are still busy acquiring the detailed articulatory specification for words and grammatical constructs, which thus have to be fully created each time they are required. In this case, the phonological memory serves as a response buffer. If there are constraints on the amount of information that can be held by the phonological memory, utterance length will be limited, expressive syntax will be immature, and vocabulary diversity will be limited (Gathercole et al, 2005).

While there may be some merit in Gathercole and colleagues' proposal, it does not appear as if this hypothesis has been tested empirically. Furthermore, as Gathercole and colleagues tend to use the term "speech production" as a synonym for expressive language (e.g. Adams & Gathercole, 1995), it is not clear if this hypothesis refers to the planning of speech specifically, or whether they are referring to expressive processes in general.

If phonological short term memory has a role in temporarily storing phonological representations (either those retrieved from long term memory, or currently stored in short term memory), this phonological information may be subject to decay. Some speech errors may thus reflect limitations of short term phonological storage. However, as yet, there is little evidence to support this view.

Speech Influences Memory

Within phonological memory, information is lost rapidly through decay or interference. Information can be maintained for a longer period through the use of efficient rehearsal processes. However, these rehearsal processes, whether overt (aloud) or covert (inner speech) would involve an element of speech production. The relationship between speech and memory has been demonstrated in tasks involving articulatory suppression, and measurements of articulation rate and pause duration.

Articulatory Suppression

It is widely accepted that articulatory suppression, which prevents an individual from rehearsing verbal material in short term memory, has a marked negative effect on performance on verbal short term memory tasks (Gathercole, Hitch, Service, & Martin, 1997). Baddeley (1997) reported that while overt articulation is not required for inner speech, operation of the phonological loop can be disturbed by the articulation (overt or covert) of an irrelevant item. This effect is restricted to distractor tasks involving articulation, as non-articulatory secondary tasks do not have a similar effect on short term memory performance; while suppression specifically affects phonological and articulatory coding, rather than

having general effects (Baddeley, 1997). Subvocal rehearsal (which would require speech abilities) is thus crucial to the functioning of the phonological loop.

Articulation Rate

Articulation rate is closely linked to the functioning of the phonological loop. Time-based forgetting refers to the fact that information is lost from the phonological short term memory within 1-2 seconds (Baddeley, 1997) unless it is refreshed. Hence any increase in the duration of subvocal rehearsal processes or time taken to produce a verbal response would affect performance on memory tasks. Support for this view comes from the word-length effect, which refers to the spoken duration of stimuli. The word-length effect is regarded as a powerful determinant of immediate memory span, where the duration of the stimulus, rather than number of syllables is the crucial feature (Baddeley, 1997).

There is a fixed and lawful relationship between verbal short term memory span and the rate at which one can articulate information (Jarrold, Hewes & Baddeley, 2000), which is consequently influenced by development. Several authors have reported that articulation rate could predict aspects of memory span (Adams & Gathercole, 1995; Gillam, Cowan & Day, 1995). Of importance in the current study are the findings of a study by Nicolson (1981 in Baddeley, 1997) who demonstrated that as children mature, they are able to rehearse faster, leading to a clear relationship between an increase in digit span with age, and an increase in articulation rate. A consistent pattern of developmental change is found for a spectrum of perceptual and cognitive tasks, whereby speeded performance improves markedly during childhood, with changes still occurring during adolescence (Kail, 1992). In particular, Kail found that cognitive processes were executed more rapidly with increases in age, which meant that words were refreshed more rapidly in the articulatory loop. Increases in age also contributed to more rapid rehearsal, which yielded more accurate recall. Adolescents would therefore be expected to have a faster articulation rate, and hence a longer memory span than younger children.

Children with speech disorders, who have a slower articulation rate, have less accurate recall than children without speech disorders (Raine, Hulme, Chadderton &

Bailey, 1991 in Kail, 1992), while in a study comparing 9-year old children to adults, Kail (1992) found that age and processing speed independently contribute to articulation speed, which determines memory. Age and the presence of speech disorders thus affect articulation rate, which in turn affects phonological memory.

Findings regarding the relationship between articulation rate and verbal short term memory capacity have two implications: Firstly, individual differences in verbal short term memory are mediated by individual differences in articulation rate; and secondly, differences in articulation time for different stimuli may explain differences in memory span across stimuli (Jarrold, Hewes & Baddeley, 2000). Jarrold et al thus proposed that recall is dependent on articulation rate either during the maintenance of information, or output of responses. Articulation rate could impact on rehearsal rate, which will determine the efficiency with which information is refreshed in the phonological store. Thus a slower rehearsal rate would limit the number of items maintained in the phonological loop. Alternatively (or additionally) the output rate of the verbal response may be a limiting factor, as output delay could also influence performance.

Pause Duration:

In addition to articulation rate, the duration of pauses between words in the output to memory tasks could constrain verbal short term memory. Pause duration may serve as an index of differences in speech planning processes, or as an index of memory search processes, such as scanning during preparation of responses (Jarrold, Hewes & Baddeley, 2000). Jarrold et al report that pause duration can predict significant variance in verbal short term performance and can affect memory span. Pause duration is reportedly sensitive to age differences, with a reduction in pause duration with age (Jarrold et al, 2000).

Both articulation rate and pause duration correlate with memory span, but there is contradictory evidence whether they correlate with each other (Jarrold, Hewes & Baddeley, 2000). The lack of a clear correlation to date may suggest that articulation rate and pause duration reflect different underlying processes, with articulation rate possibly linked to motor output, and pause duration to planning or retrieval processes.

This view would be in accordance with Jarrold, Baddeley and Phillips' (2002) conclusion that ease of planning and executing output responses can both constrain verbal short term memory performance. This conclusion has clear implications for the impact of speech deficits on memory performance.

Do Speech Deficits Limit Inner Speech or Verbal Output in Memory Tasks?:

Although there appears to be a clear relationship between speech and memory abilities, impaired speech does not necessarily constrain verbal short term memory. Evidence from neurologically impaired adults and phonologically impaired children suggests that the phonological loop alone may not be implicated in performance on memory tasks. Adams and Gathercole (2000) suggested that the relationship between nonword repetition and expressive language is due, in part, to the influence of processes involved in planning speech on rehearsal. According to Adams and Gathercole, poor nonword repetition may thus reflect impaired "inner speech". However, Baddeley (1997) reported on a number of studies involving dysarthric adults or anarthric children, who had relatively normal memory spans, with evidence of the word-length effect. Baddeley concluded that inner speech is not dependent on outer speech for its operation or its development.

Baddeley's (1997) conclusions may indirectly lend support for the idea that articulation rate is affecting output rate, rather than rehearsal rate. The existence of an articulation rate and pause duration effect is widely accepted. If, as Baddeley believes, inner speech is not affected by speech production difficulties, it would suggest that it is the articulation rate during verbal output which is constraining verbal short term memory. Hence, children with delayed or impaired speech development, who may have a slower rate of articulation, would be more likely to demonstrate a reduced memory span. Furthermore, the fact that individuals with SLI have a slower articulation rate (Tomblin, Freese & Records, 1992; Flipsen, 2002) could certainly impact on their performance on tests of phonological memory, such as nonword repetition.

Further support for the argument that motor planning and execution may be influencing performance on verbal memory tasks, comes from a study by Willis and

Gathercole (2001). In this study, the authors found that sentence repetition, but not sentence comprehension was affected by word length. Such a finding would suggest that it may not be working memory that constrains sentence processing (as participants could process sentences sufficiently for comprehension to take place), but output processes that constrain repetition.

Gathercole and Baddeley have downplayed the potential role of speech abilities on measures of short term memory (e.g. Adams & Gathercole, 1995; Baddeley, 1997). However, in a study on nonword repetition in 4-year old children, Adams and Gathercole (2000) concluded that the relationship between language development and verbal short term memory is not "only" due to common output requirements, such as articulation. Such a statement would suggest that they acknowledge at least some contribution of speech production processes to performance on verbal memory tasks, and would lend support to suggestions by authors such as van der Lely and Howard (1993) and D.V.M. Bishop, S.J. Bishop et al (1999), that formulation of articulatory programs, articulatory-motor production, or higher level phonological output processes may be implicated in tasks requiring verbal repetition.

4.4.3 Language and Memory

The relationship between language and memory has been well-documented. Since this relationship does not form a major focus of the current study, it will be summarized briefly. Of importance for the current study is the fact that speech, language and memory have reciprocal relationships and impact on each other.

Memory Influences Language Development

Short term (phonological) memory and long term memory can influence language development substantially. An important function of phonological memory, which refers to the temporary retention of verbal material, is the development of the language processing system in children. Phonological memory, as measured by nonword repetition, is related to vocabulary acquisition, syntactic development, language comprehension and reading in both children and adults (Gathercole, Willis & Baddeley, 1991; Adams & Gathercole, 1995; Montgomery, 1995, 2000a, 2002b;

Gathercole, Hitch, Service & Martin, 1997; Adams & Gathercole, 2000; Gupta, MacWhinney, Feldman & Sacco, 2003; Gathercole et al, 2005).

The relationship between verbal short term memory and language may be related to processing limitations. During language processing, several factors draw on working memory resources. Bloom and Lahey (1994, in Adams & Gathercole, 2000) suggested that individual differences in language processing reflect the amount of resources required, and the efficiency of component processes (such as lexical access). Factors such as topic familiarity and syntactic form would influence the amount of resources required. In this view, (which concurs with Just and Carpenter's model (1992, in Fazio, 1998) the relationship between working memory and language skills is not restricted to the phonological loop, but also involves the central executive. Thus processing limitations aligned to the central executive may constrain language abilities (Adams & Gathercole, 2000).

Support for a problem of resource allocation as an explanation for the relationship between language and short term memory comes from Montgomery's (2000a, 2000b) studies on sentence comprehension in children with SLI, which found that under dual-load conditions children with SLI performed much worse than normal language peers. His results led him to conclude that children with SLI have a similar memory capacity to normal language peers, but that they have a smaller functional memory capacity because as more resources are allocated to processing, fewer resources are available for storage. Thus as processing demands increase, less information is stored.

Functional memory capacity, rather than capacity of the phonological loop can thus constrain language processing, and hence constrain language development. This functional memory capacity would involve the coordination of storage and processing of verbal information, as well as the management of additional processing demands (Montgomery, 2000a, 2000b). It is the view of this study that it is functional memory capacity which is implicated in SLI, rather than just the phonological loop, and that this functional memory deficit can have a negative impact on language development. Since functional memory is dependent on the allocation of appropriate resources, any

speech impairment which affects resource allocation, would impact on performance on memory tasks.

Language Influences Memory

There is largely consensus in the literature that verbal memory does not function in isolation, and that long term linguistic knowledge influences recall. It is merely the extent of the linguistic influence that is under debate.

Arguments for a strong causal effect of language on verbal short term memory were presented by van der Lely and Howard (1993), who suggested that verbal short term memory impairments are a consequence of poor language abilities. Van der Lely and Howard proposed a "mutual output constraints" argument, suggesting that associations between spoken language and nonword repetition merely reflect the similar phonological processing and output requirements involved in such tasks. However, as noted previously, the methodology of these studies has been criticised.

A less strong view would argue that long term linguistic knowledge may impact on serial recall and nonword repetition (e.g. Gathercole, 1995; Adams & Gathercole, 2000; Nimmo & Roodenrys, 2002; Gupta, MacWhinney, Feldman & Sacco, 2003). Nonword repetition would thus be mediated by lexical representations of similar syllables (Dollaghan, Biber & Campbell, 1993; Nimmo & Roodenrys, 2002) or words (Adams & Gathercole, 1995) in long term memory, with the result that the extent of an individual's vocabulary knowledge could support or impede performance on this task. Support for this argument is provided by evidence that words are recalled more easily than nonwords; while nonwords with familiar phoneme associations are recalled more easily than those with unfamiliar phoneme associations (Gathercole & Baddeley, 1994; Gathercole, 1995; Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg, 1999). The fact that nonword repetition tends to correlate more closely to vocabulary than digit span correlates with vocabulary, has also been attributed to the influence of lexical knowledge (Gathercole, Hitch, Service & Martin, 1997).

Gathercole et al (1997) therefore argued that the phonological store relies both on short term sequential memory and the activation of representations in the lexical

system. Thus the functional capacity of the phonological loop is affected partly by "pure" capacity, which is subject to individual variation and developmental change, but also by lexical knowledge.

While the wordlikeness effect described above has been attributed to lexical knowledge, phonological pattern frequency (Munson, 2001), and syllable gesture scores (Levelt & Wheeldon, 1994) may also have an effect on nonword repetition. Ratings of the wordlikeness of nonwords were correlated with the pattern frequency of sequences embedded in them (Munson, 2001). Less frequent sequences of phonemes were repeated with less accuracy and with longer durations, leading Munson to suggest that the speed and accuracy with which a sequence of sounds is encoded for production is related to the phonological pattern frequency. Lexical knowledge is thus only one factor influencing the wordlikeness effect in sequential memory tasks. Accuracy and speed of encoding for speech would account for some of the variance. Similarly, Levelt and Wheeldon demonstrated that it is likely that individuals have a store of syllable gestures for regularly used syllables. Hence high frequency syllables are produced with fewer errors than low frequency syllables because of ease of articulatory specification, and not necessarily because of memory alone.

While the lexical effect has some influence on performance on memory tasks, speech deficits may also account for poor performance in children with SLI. Montgomery (1995) found that in a nonword repetition task, children with normal language abilities showed a gradual decrease in performance as the length of the stimuli increased. Children with SLI, in contrast, showed a precipitous decrease in performance for stimuli of more than two syllables. He interpreted these findings to suggest that it was limited phonological memory (demonstrated in a length effect), rather than impaired lexical knowledge which influenced performance. However, since speech performance is also affected by length in terms of the phonological complexity of an utterance, the length effect may point to speech production factors, and not just to memory factors.

A process of "redintegration" has been proposed to counteract the effects of forgetting in verbal short term memory (Jarrold, Baddeley & Phillips, 2002). Redintegration implies that knowledge of the possible identity of items to be recalled, or of likely phonological constraints within the language, facilitate recall. An individual therefore benefits if he/she has a larger lexicon or better knowledge of the properties of language. However, if language is impaired, an individual would benefit less from the top-down effect of long term linguistic knowledge on short term verbal recall. Individuals with SLI may therefore lack the linguistic skills to use redintegration effectively. Redintegration is affected by developmental factors. Adolescents would therefore be able to use redintegration more effectively than younger children.

4.4.4 Speech, Language and Memory

As is illustrated in Figure 4-1 and discussed above, reciprocal interactions exist among language, speech and memory. Any task requiring verbal output may be influenced by abilities in all three these areas. If these three areas are inextricably linked, any difficulties with speech production will impact on language and memory abilities. It is the view of this author that even subtle speech impairments would interact with language and memory abilities. A subtle impairment in one of these areas may not impact noticeably on performance on verbal output tasks. However, when considering the threshold effect discussed above, the more severe the impairment in any one area (speech, language or memory), and/or the more areas which are impaired, the more likely it is that performance on any given task will be compromised because of capacity limitations.

Impairment in any one area may affect the automaticity of performance. Thus, in an undemanding task, where resources can be allocated to aid controlled performance, impairment may not be evident. As the complexity of tasks increases, requiring the allocation of more resources, there may be insufficient resources to complete a task efficiently and accurately, which may result in a breakdown of performance. Assessing speech abilities in an undemanding task, as has been done in

many studies on language and memory abilities in children with SLI, may not uncover subtle deficits, including a reliance on controlled, rather than automatic processes. Yet, when linguistic and memory demands increase, a subtle speech impairment could either have a direct effect on language and/or memory abilities, or such a speech impairment would place higher demands on available resources, reducing the resources available for the linguistic and memory components of the task.

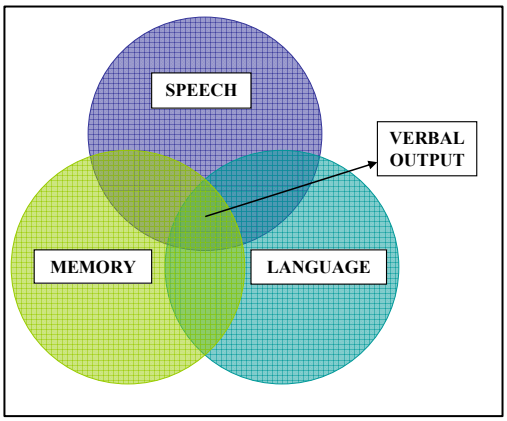

Figure 4-1: Interactions among language, speech and memory.

4.4.5 Nonword Repetition as an Assessment of Memory

Since much of the information presented in this chapter relate to findings involving nonword repetition and researchers are increasingly using this tool to study SLI, this assessment tool should be examined in more detail. There are two primary concerns regarding the use of nonword repetition as a test of "pure" phonological memory. Firstly, the task may assess more than phonological memory capacity, and secondly, there is much overlap in scores between groups used in research studies.

Does Nonword Repetition Assess Only Phonological Memory?

Numerous studies have shown that children with SLI perform poorly on tests of nonword repetition (Bishop, North & Donlan, 1995; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1990; Ellis Weismer et al, 2000). Nonword repetition serves to differentiate children with SLI from unimpaired children with high sensitivity,

specificity and accuracy even when the language impairments appear to have resolved on other standardised language tests (Montgomery, 1995; Stothard, Snowling, Bishop, Chipcase & Kaplan, 1998).

Gathercole, Baddeley and colleagues have proposed that nonword repetition is a purer measure of phonological working memory capacity than real words (e.g. Gathercole, Willis & Baddeley, 1991), as performance on this task reflects the capacity to maintain or store phonological material in the articulatory loop without the support of lexical or semantic familiarity (Ellis Weismer, et al, 2000). Since nonword repetition is not dependent on prior knowledge and experience, it is regarded as a culturally unbiased test, as it is processing, rather than knowledge-based (Campbell, Dollaghan, Needleman & Janosky, 1997). For a similar reason, nonword repetition has been proposed as a good processing-based measure to use in order to distinguish children with SLI from those with normal language abilities (Dollaghan & Campbell, 1998). The idea of nonword repetition as a "pure" measure of memory, however, has been debated.

In order to repeat a nonword accurately, several processes are involved (Montgomery, 1995; Edwards & Lahey, 1998; Snowling et al, 1991 in Gupta, MacWhinney, Feldman & Sacco, 2003). Firstly, the acoustic signal has to be perceived and discriminated. Secondly, acoustic information must be encoded into a phonological representation; and thirdly, this phonological representation must be held in working memory, probably through rehearsal processes. Fourthly, the response must be planned and executed. In the view held by Gathercole and Baddeley, nonword repetition would reflect a breakdown at the third stage of this process, while they have concluded that the other three phonological processes do not make a strong contribution to group differences in nonword repetition ability (e.g. Gathercole & Baddeley, 1990).

Factors related to speech perception, phonological representations, articulatory processes, and processing limitations will now be discussed.

There is some evidence for the influence of factors related to speech perception. For example, James et al (1994 in Majerus, Vrancken & van der Linden, 2003)

reported that impaired speech perception accounted for poor performance on verbal short term memory tasks by SLI participants.

There have been arguments that nonword repetition may be affected by metaphonological processes such as segmentation and blending (e.g. Snowling, Chiat & Hulme, 1991 in Montgomery, 1995; D.V.M. Bishop, S.J. Bishop et al, 1999). It is commonly accepted that children with SLI demonstrate delayed acquisition of metalinguistic abilities, especially syllable and phoneme segmentation (Montgomery, 1995), hence the impaired metaphonological skills of children with SLI may impact on their ability to produce nonwords. However, thus far there is little data to support this hypothesis. Metsala (1999 in Ellis Weismer et al, 2000) suggested that since children with better vocabularies are also known to have better segmentation abilities, the close relationship between vocabulary and nonword repetition may reflect the influence of segmentation abilities in mediating nonword repetition.

Particularly with regard to speech output factors, some authors have concluded that the impact of these factors is negligible. Their conclusions are based on studies which have shown that children with SLI and those with normal language ability have comparable articulation rates of words of one and three syllables (Gathercole & Baddeley, 1990; Adams & Gathercole, 1995), and that these groups do not differ in their repetition rate for strings of nonsense syllables (Stark & Montgomery, 1994, in Montgomery, 1995). However, the Gathercole and Baddeley findings were based on repetitions of simple words, with no additional processing load. Ellis Weismer et al (2000) tried to control phonological output factors by evaluating whether the required phonemes were in their participants' phonetic repertoire. However, asking children to repeat words or nonsense syllables that are well within their phonological and lexical capabilities does not provide an indication of whether these children can maintain the same performance when there is an increased demand on resources.

It is interesting to note that Stackhouse and Wells (Stackhouse, 2000) regard nonword repetition as a speech output task which assesses children's ability to assemble and execute new motor programmes for unfamiliar words. At least one study (Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg, 1999) reported that

output phonology was a strong predictor (in fact the strongest predictor) of nonword repetition ability. Botting and Conti-Ramsden (2001) also found that high scores on a standard articulation test correlated with high scores on a nonword repetition task at age 7 years. Hence, speech output factors cannot be ignored in considering nonword repetition tasks, and in fact, Sahlén et al concluded that if nonword repetition performance is influenced by output phonology, it cannot be regarded as a processing-dependent measure.

Nonword repetition may be related to motor development. Nonword repetition involves speech motor control as it entails preparation and execution of a speech movement sequence, and not just the combined influence of auditory memory and phonologic processing (Kent, 2000). Munson (2001) reported that in nonword repetition, children, but not adults, repeated infrequent sequences of phonemes less accurately than frequent sequences. In particular, infrequent sequences were produced with longer durations than frequent sequences, and children demonstrated a larger difference between frequent and infrequent sequences than adults. Munson (2001) also reported that frequent words are reported with shorter acoustic durations and are produced with fewer spontaneous speech errors than infrequent words. A study by Beckman and Edwards (2000, in Munson, 2001) suggested that acquisition of more mature speech production involves a gradual increase in flexibility. Thus older speakers have abstracted a more localized motor representation for individual sounds, which allows them to be produced accurately in less familiar contexts. Hence, performance on tests of nonword repetition, particularly in children, may reflect motoric limitations.

A limited processing capacity could be implicated in nonword repetition errors, as presentation rate (Fazio, 1998) and format (Goolkasian & Foos, 2002) both affect recall, lending strong support for a resource allocation model to explain working memory deficits. After an analysis of errors produced on a nonword repetition task, Edwards and Lahey (1998) concluded that it is not necessarily a test of working memory. They suggested that slight problems with certain of the processes involved in nonword repetition may interact with the task to produce a higher rate of

inaccuracies. Hence processing limitations would result in an increase in inaccuracies under conditions of stress. With regard to the motor execution of responses, they concluded that there was no strong support for a hypothesis that limitations of motor execution can affect performance on nonword repetition tasks. However, they could also not find sufficient evidence to reject such a hypothesis.

Should a limited processing capacity be implicated in nonword repetition, it would have implications for the evaluation of contributing factors. Assessing phonological representations or motor execution in isolation would not be helpful. The question is not whether an individual can demonstrate a particular skill using simple stimuli in unstressed conditions. The real question is whether the individual can perform the task with sufficient automaticity to maintain his/her performance under conditions of increasing stress. While researchers are becoming increasingly aware of the need to control for the impact of long term lexical and phonological knowledge through the construction of their nonword tasks (e.g. Dollaghan & Campbell, 1998), it would be more difficult to control for the other factors. In order to make inferences regarding the potential impact of other factors on nonword repetition (or any assessment task requiring verbal responses) it would be helpful to determine whether skills in those areas, including articulation are robust. Automaticity of those skills and the ability to maintain performance when there is an increasing demand on resources may allow one to make inferences regarding the likelihood that performance in those areas would be maintained on a resource-demanding task such as nonword repetition.

There may therefore be multiple causes for nonword repetition deficits (see Figure 4-2), with causes differing across different types of language impairment, as well as within the SLI population (Ellis Weismer et al, 2000). For example, in children with Down Syndrome impaired receptive vocabulary, rather than auditory or speech difficulties, contributed to performance on verbal short term memory tasks (Jarrold, Baddeley & Phillips, 2002). High error scores may thus reflect different underlying impairments for different individuals.

There is thus some evidence to suggest that the effects of motor planning and execution on nonword repetition cannot be ruled out, while the task is also influenced by auditory perception, phonological representations, phonological loop capacity, lexical knowledge and processing capacity. As this study will demonstrate, children with SLI frequently have speech deficits related to motor planning and execution. One could assume that such deficits may impact on nonword repetition. There would therefore be strong indications that the potential impact of speech output factors on nonword repetition should be investigated further, as the characteristic poor performance of individuals with SLI on nonword repetition tasks may be related, in part, to speech output factors.

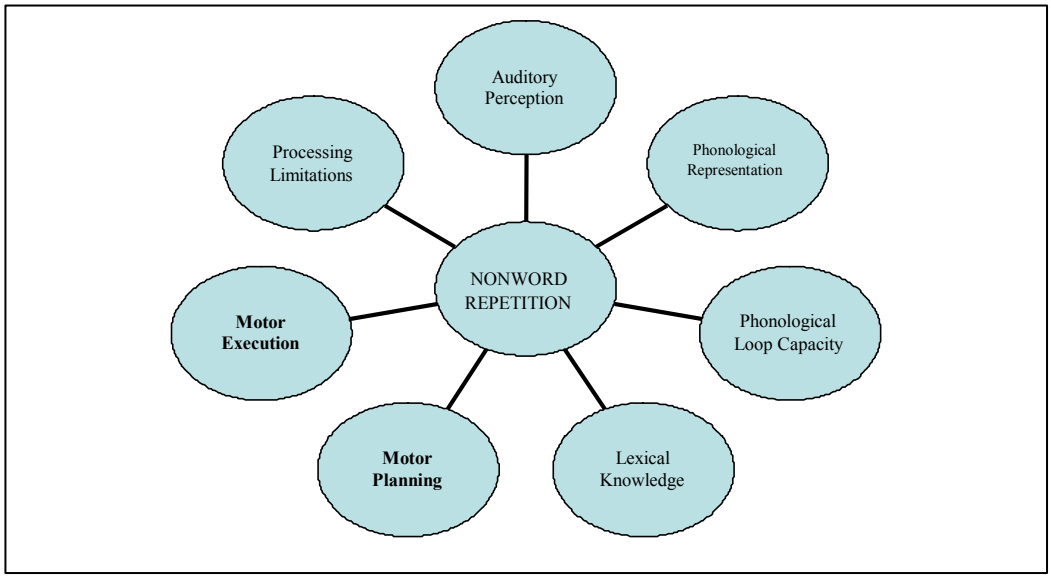

Figure 4-2: Factors impacting on nonword repetition.

Variability of Nonword Repetition Performance within Groups

There is no question that there are differences in mean scores for nonword repetition between groups when comparing, for example, children with SLI to children with typical language development. However, several studies have reported much overlap of scores between SLI and normal language groups (Edwards & Lahey,

1998). Whether using a simple right/wrong scoring system (Adams & Gathercole, 2000) or percentage consonants correct (Ellis Weismer et al, 2000), scores overlapped. In Bishop, North and Donlan's (1995) study, for example, some children with language impairment obtained nonword repetition scores within the normal range. Accordingly, Dollaghan and Campbell (1998) suggested that just because groups differ on a particular measure, one cannot assume that the measure will accurately identify language impaired versus non-language impaired individuals.

Ellis Weismer et al (2000) conducted likelihood ratio analyses to evaluate the clinical utility of nonword repetition as a diagnostic tool, and concluded that while nonword repetition performance may *assist* in ruling language disorder in or out, it was not sufficient on its own and needed to be supplemented by other language measures. With regard to the diagnostic utility of nonword repetition to identify SLI specifically, it should be remembered that nonword repetition also reflects language ability in populations other than SLI, such as Down Syndrome, autism, and acquired language deficits such as Landau-Kleffner Syndrome (Botting & Conti-Ramsden, 2001). Thus nonword repetition tasks cannot be reliably used to distinguish children with SLI from other types of language impairment.

Although we are currently not sure exactly what is measured by nonword repetition, and whether nonword repetition deficits reflect different underlying impairments in different individuals, the task nonetheless has utility as a research and diagnostic tool. It is clearly sensitive to some aspects of processing ability that are closely linked to language acquisition in clinical and non-clinical populations, adults and children. Bishop, North and Donlan (1995), for example, found that nonword repetition was a good phenotypic marker of developmental language impairment and provided high estimates of heritability. Nonword repetition may also identify subclinical language impairment (D.V.M. Bishop, S.J. Bishop et al, 1999). Nonword repetition thus has predictive value, and within an assessment battery, it has diagnostic value. Nonetheless, the limitations of this measure must be acknowledged.

4.5 Speech Disorders in SLI: Implications for Research

The co-occurrence of speech disorders with SLI has at least two implications for research, involving participant selection, and determining the influence of speech disorders on verbal tasks.

4.5.1 Exclusion of Phonological Impairment as Selection Criterion

Research involving preschoolers with SLI has often excluded children with speech sound disorders or stipulated that phonological skills should not be markedly further below age level than the estimated language age (e.g. Stark & Tallal, 1981a; Leonard, McGregor & Allen, 1992; Aram, Morris & Hall, 1993; Ellis Weismer & Hesketh, 1996; Leonard, Eyer, Bedore & Grela, 1997; Montgomery, 2000a, 2002a; Frazier Norbury, Bishop & Briscoe, 2002). This criterion appears to serve two purposes: Firstly, it supposedly excludes children who may primarily have a speech disorder of motor origin; and secondly, it excludes unintelligible children from studies on expressive language (particularly expressive morphosyntax). As was discussed in Chapter 3, motoric impairments are not unusual in children with SLI, suggesting that the reasoning behind the first purpose is questionable. The second purpose is clearly a matter of expediency, yet the potential impact of excluding the very children who have a typical SLI profile i.e. varying areas of strength and weakness in a number of language domains, is seldom acknowledged.

The implication is that these studies have only evaluated a subset of the larger SLI population (those without severe phonological deficits). From the above discussion it is apparent that it is common for children with SLI to have speech sound disorders, and many children with SLI appear to have phonological skills that are more delayed than their lexical abilities (Leonard, 1998). Excluding such children from research in SLI thus leads to biased sampling.

The speech error criterion is also not applied consistently across the age span and often depends on the construct under investigation. Studies involving school-aged children, by which stage speech sound disorders are usually largely resolved, do not consider speech errors (or a history of speech errors) as an exclusionary criterion. Similarly, studies involving constructs which do not require verbal output (such as

studies on receptive language or nonverbal abilities) often make no mention of a speech error criterion. Consequently, replicability (reliability) and generalizability (external validity) of research findings in the area of SLI are reduced.

4.5.2 Determining the Impact of Speech Production Factors on Verbal Output Tasks

Researchers often attempt to determine the potential impact of speech production factors on performance on verbal tasks. Often these researchers have been influenced by questionable assumptions, affecting methodological decisions. Most of the studies have concluded that speech abilities in children with SLI without overt phonological disorders do not impact substantially on their performance on memory tasks or language tasks (e.g. Adams & Gathercole, 1995, 2000), yet this may not be entirely true.

The first questionable assumption is that in order for speech abilities to impact on performance on memory or language tests, children with SLI should have consistent difficulty articulating specific sounds. Studies such as those by Kamhi and Catts (1986) and Kamhi, Catts, Mauer, Apel and Gentry (1988) which have shown that consistent errors are rare in older children, is taken as evidence that speech is not impaired in older children with SLI. The presence of inconsistent, context-dependent errors in speech impaired populations is disregarded.

A second assumption is the idea that planning and execution of complex phonological sequences can be evaluated by investigating the presence/absence of clear phonemic contrasts across syllables (Kamhi & Catts, 1986) or the production of consonant singletons versus clusters (Bishop et al, 1996 in Edwards & Lahey, 1998; Gathercole & Baddeley, 1990) which does not consider the possibility of inconsistent errors. These studies yielded conflicting results, with Gathercole and Baddeley reporting no differences among groups, while Bishop et al and Kamhi et al did find differences.

The third questionable assumption is that measurements of articulation rate or latency on simple items would identify differences in speech production between children with SLI and normal language controls, without considering the impact of

resource allocation in more demanding tasks. Studies by Gathercole and Baddeley (1990) and Montgomery (1995) indeed have found no differences between children with SLI and controls on these measures.

The above assumptions are questionable, because if the speech impairment in SLI is subtle, errors or differences in latency and rate may not be evident on simple tasks, such as repeating monosyllabic words of low semantic load, as resources can be concentrated on this one task. With an increase in task complexity, such as when the task places demands on memory or linguistic processing, fewer resources can be allocated to speech production. In a vulnerable speech production system breakdown in speech under these resource-intensive conditions is likely to be seen in inconsistent errors, rather than difficulty with specific sounds. It is therefore not surprising that authors such as Ellis Weismer et al (2000) or Dollaghan and Campbell (1998) found that their participants' phonetic repertoire did not impact on nonword repetition performance. The issue is not merely whether an individual is able to produce a specific sound or syllable structure, but whether he/she can maintain that performance in resource-demanding tasks. Adams and Gathercole (2000) proposed that further work should be undertaken to investigate performance limitation accounts of speech production in language impaired populations, a proposal which is supported by the current study.

In summary, assumptions regarding speech production abilities of children with SLI, have led to questionable decisions regarding participant selection for studies, and selection of tasks to determine the impact of speech production factors on verbal output tasks. It is clear that more information is needed regarding speech production in SLI, to determine if such decisions are of value.

4.6 Methodological Considerations

As a result of the above discussion, the following factors were borne in mind when designing the current study:

- Any language assessment has to include tasks that tap higher level syntactic and semantic abilities as adolescents face more complex language demands.

- Differences in the physical development of the speech system between males and females dictate that the groups included in this study should include equal numbers of male and female participants.
- The contextual factors identified by van der Merwe (1997) as well as factors identified in the study of speech errors (see 2.5) have to be controlled when selecting tasks for a speech assessment battery, particularly with regard to length of stimuli, familiarity, phonological and motoric complexity.
- As speech, language and memory abilities interact in verbal output tasks, it was necessary to assess all three these areas to explore correlations among these three areas.
- Nonword repetition is one of the most frequently used assessment tools in the area of SLI and thus had to be included in the memory assessment battery. Including a nonword repetition measure also allows for the identification of correlations with speech measures, which could lend support for the hypothesis that speech output factors may constrain nonword repetition.

4.7 Summary and Conclusions

SLI frequently persists into adolescence and adulthood when individuals are faced with more challenging cognitive and linguistic demands. Speech development is not complete when children have acquired all the speech sounds of their language, but continues into adolescence, particularly with regard to auditory perceptual, phonological, physical, motoric and neurological aspects of development. Adolescents therefore continue to face the challenge of managing a developing speech system in the face of increased linguistic and cognitive demands. This challenge is even more pertinent to adolescents with SLI, who have linguistic deficits and who frequently have a history of speech impairment. Factors influencing speech production in typical adolescents may therefore have an even greater impact in adolescents with SLI, who may be faced with both linguistic and motoric challenges. However, the redundancy of the speech system may ensure that speech deficits do not always result in overt speech errors. Instead, subtle difficulties such as dysfluencies

or reduced speech rate may result. In some instances, tradeoffs may occur, where more resources are diverted to speech production, leaving fewer resources for language processing, with a resultant impact on language production. Particularly in view of the reciprocal interactions among speech, language and memory discussed above, speech production deficits in adolescents with SLI may therefore impact on language and memory functioning in this population.

Nonword repetition, which is seen as a useful assessment for phonological memory, may be influenced by a number of other factors, including speech planning and execution. The presence of speech deficits in an adolescent SLI population may therefore have implications for the use of this assessment tool.

The presence of speech disorders in adolescents with persistent SLI have substantial implications with regard to participant selection criteria and the evaluation of task performance in studies involving SLI.

From the discussion in this chapter, as well as preceding chapters, it is clear that speech production in adolescents with SLI, an area which has been neglected thus far, is an important area to investigate. Speech deficits in this population, which may have been masked by the redundancy of the speech system or by processing tradeoffs, would not exist in isolation, but could have far-reaching implications for functioning in other areas of language and cognition.

The following chapter provides a more detailed discussion of the conceptual and methodological factors which influenced the development of this study.

5 Conceptual and Methodological Considerations

This chapter aims to serve as a bridge between the previous three background chapters and the method described in Chapter 6. It provides a conceptual and methodological background to the current study and serves to elucidate and justify some of the methodological decisions described in the following chapter. Three pertinent aspects are discussed in this chapter. Firstly, definitional issues in specific language impairment (SLI) are discussed, particularly as it relates to difficulties in operationalising the definition of SLI for participant selection. Secondly, the development of the Speech Assessment Battery used to identify speech deficits in this study is described with reference to the models underlying the selection and analysis of tasks. The chapter ends with a brief discussion regarding clinical versus research significance of results obtained in research studies, with implications for the current study.

5.1 Defining Specific Language Impairment in Adolescence

While there is substantial agreement in research literature regarding the definition of SLI, there is much controversy regarding selection criteria for individuals with SLI. Overall, researchers have used different methods to operationalise the definition of SLI for participant selection. Researchers also acknowledge that the standard criteria established by Stark and Tallal (1981a) may not be applicable to older children. This lack of consensus in the field, coupled with the fact that criteria often apply primarily to younger children, necessitated careful consideration of issues related to the selection of adolescent participants for the current study.

The current study has adapted the criteria proposed by Stark and Tallal (1981a) (generally regarded as the gold standard adopted by most researchers), Leonard (1998) and Plante (1998), while holding to the definition of SLI as being an unexpected and unexplained language disorder, which cannot be attributed to sensory, motoric, physical, intellectual, frank neurological or social interaction deficits (Leonard, 1987; Tomblin, Smith & Zhang, 1997; Leonard, 1998; Kamhi, 1998; Plante, 1998).

As was mentioned in Chapter 3, there is much variability regarding the definitions and procedures used to operationalise the discrepancy, inclusionary and exclusionary criteria commonly used to identify children with SLI. In 1996, Dunn, Flax, Sliwinski and Aram stated that no generally accepted method for the identification of children with SLI existed at that time. Eleven years later this issue is still unresolved. Researchers and clinicians often employ different criteria, and children included in research samples are seen as constituting only a small proportion of the population of children with SLI diagnosed by clinicians (Stark & Tallal, 1981a; Aram, Morris & Hall, 1993). In the section below, the inclusionary, discrepancy and exclusionary criteria used in the current study are described and justified with reference to current practices recorded in the research literature. (See Table 6-1 in Chapter 6 for a summary of criteria used in this study).

5.1.1 Inclusionary and Discrepancy Criteria

Psychometric discrepancy criteria were not used in isolation in the current study, as there are too many theoretical and practical criticisms of this construct, and it has been found that discrepancy criteria may be over-exclusive (D.V.M. Bishop, S.J. Bishop et al, 1999). To support this decision, a brief review of relevant literature will be presented.

Tallal (1988 in Aram, Morris & Hall, 1993) emphasized the need to demonstrate that language abilities are below chronological age expectancies and significantly discrepant from mental status. She proposed the development of standardized inclusionary and exclusionary criteria, using a psychometric reference. In principle this sounds easy to do, however, quantifying language performance and non-verbal abilities can be difficult, and the reference for determining discrepancy varies (Aram, Morris & Hall, 1993).

Language Discrepancy Scores

The participants in this study had to obtain scaled scores below 80 on at least two language measures during the previous two years (D.V.M. Bishop, S.J. Bishop, et al, 1999) and language impairment had to be diagnosed by the participants' Speech-language pathologist. As suggested by Plante (1998, p.956),

"…the combination of test-based data and clinical judgment of impairment provides the converging evidence of impairment that underlies previous recommendations that multiple measures be used in the diagnosis of SLI".

Multiple language measures were used to identify SLI participants. The use of a single aspect of language, such as syntax, for comparison is inappropriate (Aram, Morris & Hall, 1993; Dunn, Flax, Sliwinski, & Aram, 1996), when language is a multifaceted construct. This issue is complicated even further when evaluating adolescents, whose language involves abstract and complex concepts and constructions which have reciprocal relationships. Quantifying the language ability of adolescents using single measures is thus inappropriate and unrealistic.

For this study results from a single language test were used to identify participants with SLI, provided that the test consisted of a number of subtests, evaluating both receptive and expressive language, and at least morphosyntax and semantics. The use of a battery of tests to identify SLI participants was regarded as inappropriate. Comparing test scores derived from different theoretical bases and standardization populations is a psychometrically incorrect practice (Aram, Morris & Hall, 1993; Plante, 1998). Several researchers have resorted to the use of a battery of tests to identify language impairment (e.g. Bishop, 1992; Ellis Weismer & Hesketh, 1996; Miranda, McCabe & Bliss, 1998; Johnson et al, 1999; Frazier Norbury, Bishop & Briscoe, 2000; Montgomery, 2002), presumably to avoid identifying SLI on the basis of one test score. However, as Plante (1998) pointed out, unless tests are co-normed on a single normative sample, norm-referenced scores obtained are not necessarily equivalent in scaling, which can produce marked differences in scores obtained across tests. The use of a battery of different tests to identify SLI is thus also questionable.

The cut-off for language scores was set at 1.3*SD* below the mean for the participant's age. The cut-off used for language scores varies substantially across studies, from 1SD below the mean (Leonard, McGregor & Allen, 1992; Frazier Norbury, Bishop & Briscoe, 2002; Flax et al, 2003), 1.25*SD* below the mean (Hammer, Tomblin, Zhang & Weiss, 2001), 1.3*SD* below the mean (Lahey & Edwards, 1995), 1.5*SD* below the mean (Gillam & Carlile, 1997; Kaderavek & Sulzby, 2000), 2*SD* below the mean (Miranda, McCabe & Bliss, 1998; Johnson et

al, 1999), or 3*SD* below the mean (Gray, Plante, Vance & Henrichsen, 1999). Researchers also differ as to whether they used single subtests, or composite scores. There is thus currently no "gold standard" to follow. Furthermore, most research on children with SLI has been done with participants below the age of twelve years. There is no certainty that any of these criteria could be applied with confidence to adolescents. As Lahey (1990, in Plante, 1998) pointed out, it is conceptually difficult to determine how low a cut-off point for test scores should be set. A score of 1.3*SD* below the mean was selected to ensure that the participants would present with some language difficulties, while allowing for the fact that participants' last language scores were likely to have occurred after a period of language intervention, and thus may not reflect the severity of the initial language disorder.

Nonverbal IQ and Cognitive Referencing for Adolescents

The nonverbal IQ criterion used in this study only served to exclude intellectual deficits which preclude a diagnosis of SLI. Participants thus had to meet two criteria: a) the participant should have a nonverbal IQ of 80 or above on an individual intelligence test in the past (which is in accordance with procedures followed by D.V.M. Bishop, S.J. Bishop, et al [1999]); and b) the participant should not currently be placed in an educational setting which caters for children with cognitive deficits. No discrepancy between language score and nonverbal IQ was required due to erroneous assumptions and issues relating to measurement of nonverbal IQ.

There is an erroneous assumption that verbal and non-verbal abilities, or the test scores to measure these abilities, should be on the same level for any given child (Dunn, Flax, Sliwinski & Aram, 1996). The use of a 1*SD* discrepancy score between language score and non-verbal IQ assumes that few or no typically developing children could have language/performance discrepancies as large as 1*SD* (Dunn et al, 1996), which is not the case.

There is little point in matching research participants by non-verbal IQ, as identical scores may reflect different abilities in SLI children as opposed to typically developing peers. Typically, children with SLI have lower non-verbal IQ scores than their normally developing peers (Swisher, Plante & Howell, 1994).

There are also group differences with regard to the extent to which performance on certain items within tests contribute to total test scores (Swisher & Plante, 1993; Swisher, Plante & Howell, 1994). Thus, even when children with SLI and their peers obtain identical scores, the numerical values may mask underlying group differences in skills. Swisher et al (1994) suggested that non-verbal IQ scores in learning impaired children do not reflect the construct of "general intelligence" in the same manner as for typically developing peers, and later Krassowski and Plante (1997) have suggested that IQ scores for children with SLI can be more properly interpreted as reflecting current abilities, rather than potential for language learning.

The non-linguistic deficits of children with SLI can adversely affect their responses on non-verbal IQ tests. For example, several studies have identified problems with anticipatory imagery tasks (such as spatial rotation tasks), analogical reasoning, and manual-motor skills in children with SLI (Swisher, Plante & Howell, 1994; Leonard, 1998), which would impact markedly on their performance on tests of non-verbal IQ.

It was decided to accept any non-verbal IQ score which qualified the participant for this study, regardless of when the test was done. IQ scores may identify a child as SLI at one age, but not another, possibly with no change in language status. Demands on tests of non-verbal IQ may be different at different ages (Johnston, 1982 in Dunn, Flax, Sliwinski & Aram, 1996). For example, preschool tests of non-verbal ability depend on visual perception, non-verbal problem-solving and conceptualization, but are also largely dependent on fine motor abilities. These tests are thus biased against children with SLI, many of whom are reported to have fine motor deficits (Hill, 2001). Similarly, tests for older children are more heavily reliant on the use of verbal mediation strategies to improve performance (Nelson, 1993, in Dunn, Flax, Sliwinski & Aram, 1996), thus also biasing tests against children with SLI, who do not have good verbal skills.

This study was reliant on retrospective test data for nonverbal IQ scores. Participants would have been tested on a range of different nonverbal measures, which can produce different results. For example, Swisher, Plante and Howell

(1994) demonstrated that mean IQ score varied as much as 10 points over three different IQ measures commonly used with children with SLI; and depending on the measure used, between 56-94% of the sample met the diagnostic criteria for SLI. It would thus have been ideal to control the use of IQ tests with the sample population to one test. However, as the researcher was dependent on retrospective data for IQ scores, this could not be done.

As there is some evidence that non-verbal IQ may decrease over time in children with SLI, and considering that an adolescent population was used for this study, a cut-off of 80 was used for the non-verbal IQ, in order to exclude children with mental retardation. The cut-off criterion for non-verbal IQ has varied across studies. Stark and Tallal (1981a) originally proposed a cut-off of 85, to offset the impact of language impairment on verbal IQ, with the resultant impact on full scale IQ. Subsequent researchers have applied this cut-off of 85 to tests which only assess non-verbal IQ, where the impact of verbal IQ did not need to be considered, while other researchers have selected a cut-off of 70 (or 75 if they considered standard error of measurement). Since full-scale IQ tests were used with the participants in this study, a cut-off score of 85 would be appropriate. Since nonverbal measures used with older children may be reliant on verbal mediation (Dunn, Flax, Sliwinski & Aram, 1996), which would penalize children with SLI, a slightly lower cut-off was set.

It was important to set the cut-off well above the 70 cut-off for mental retardation, so that, even if the nonverbal IQ score did change in the intervening period, it should not change the participant's eligibility status. Language ability and nonverbal IQ are not stable constructs. Both constructs can change over time because of maturation, intervention or the tests used for measurement. For example, Cole (1996 in Kamhi, 1998) reported that over an 8 month period, children in his study could change eligibility status, or that status could change depending on the tests used. Other longitudinal studies (e.g. Rutter, Mawhood & Howlin, 1992; Johnson et al, 1999) reported that participants with SLI (who initially met all criteria), developed exclusionary conditions over the course of the study, as their non-verbal IQ dropped below the set criterion. Krassowski and

Plante (1997) also reported significant variability in IQ scores across a 3-year period for children with SLI.

Since no discrepancy criteria were used to identify participants, some authors would argue that these participants could not be diagnosed as having *specific* language impairment, and that only the term "language impaired" would apply (Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg, 1999). However, since the exclusionary criteria for SLI were applied strictly, it was felt that these participants match the description of SLI more closely than that of generalized language impairment.

Clinical Diagnosis of SLI

A clinical diagnosis of language impairment was required for inclusion in the study, as the language cut-off score was fairly lenient. It is commonly accepted that there is lack of congruence between clinical and research definitions of SLI (Aram, Morris & Hall, 1993; Dunn, Flax, Sliwinski & Aram, 1996; Kamhi, 1998). For example, in the Aram et al (1993) study, agreement between researchers and clinicians ranged from 20-71%, depending on the psychometric measures used. Research on SLI has sometimes been criticized for using very lenient language cut-off scores (e.g. 1*SD* below the mean), which can be argued to form part of the range of normal language ability. In view of its clinical emphasis, this study wanted to include participants who had language deficits severe enough to warrant intervention, thus requiring a clinical diagnosis of SLI.

Use of Age Scores and Chronological Age Referencing

No age scores were used in this study. Several researchers have used age scores rather than standard scores to determine discrepancy (e.g. Stark & Tallal, 1981a). The discrepancy required between language age and chronological age or grade level varied from 6 months to 4 years, with some criteria applied across the board to a variety of chronological ages (Dunn, Flax, Sliwinski & Aram, 1996), which is clearly inappropriate. Furthermore, Lahey (1990, in Dunn et al, 1996) reported that a delay of 2 years is often regarded as significant, while standard scores based on such a discrepancy may fall within 1*SD* from the mean for that age. The use of age scores is clearly unreliable, particularly for an adolescent

population, where the range of what is regarded as "normal" for any age, is very wide.

Chronological age referencing[26] was regarded as inappropriate with an adolescent population. In view of the many difficulties identified in relation to cognitive referencing, some authors (Kamhi, 1998) have suggested the use of chronological age (CA) referencing. However, CA referencing also has its problems. Since normal children are used for the standardization of tests, it is not clear how low scores should be for a child to be regarded as disordered; and it is difficult to identify disorders in areas where development is not linear and continuous, such as language (Kamhi, 1998). By adolescence, the use of CA referencing is probably inappropriate. Language abilities develop at different rates in different children, and the reciprocal relationships between oral and written language development can further influence individual differences. As a result there is huge variation in the language abilities of even typically developing adolescents at any given age. The use of CA referencing with this age group cannot be justified.

5.1.2 Exclusionary Criteria

Exclusionary criteria for the identification of SLI are much more readily accepted by researchers than discrepancy criteria, and there is very little discussion in the literature regarding these criteria. However, a review of research studies suggests that the assumptions underlying these criteria and the implementation of criteria should be scrutinized more carefully, particularly with regard to an adolescent population with SLI.

Severe Phonological Disorders and/or Other Speech Disorders

Children with previously diagnosed speech disorders other than phonological disorders were not included in the study, as the presence of such disorders may have affected their performance on the speech tasks.

The current study elected not to exclude any phonological disorders, provided the participants also had a language disorder. The criterion regarding phonological disorders appears to be very flexible, and is applied as it suits the

[26] Chronological age referencing refers to a comparison between chronological age and language age.

investigators involved. Phonological disorder is defined by Leonard (1998, p.13) as "…a sound system that is underdeveloped or otherwise deviates from that of the ambient language". Children with phonological disorders are only diagnosed as having SLI if they also show deficits in other aspects of language (Leonard, 1998).

In the original criteria proposed by Stark and Tallal, (1981a) an articulation impairment could not be more than six months below the estimated expressive language age (as determined on a standardized articulation test), as this could indicate a mixed language-motor impairment. The obvious difficulties of using age-based criteria aside, the suggestion that phonological skills may not be markedly lower than other language skills is not congruent with what is known about SLI. As Aram (1991) pointed out, children with SLI vary in the degree to which they experience difficulty comprehending and producing multiple components of language (phonology, morphology, syntax, semantics and pragmatics). It is thus theoretically possible that some children with SLI have phonological abilities which are much worse than, for example, their syntactic abilities. It would thus be paradoxical to exclude children who are typically SLI in that they show variability in their profile of language abilities.

Many researchers choose to exclude participants with certain phonological disorders. As many of the studies on preschoolers with SLI have involved expressive morphology or other measures of expressive language, investigators have excluded children with sound errors which could affect their performance on experimental tasks (e.g. Ellis Weismer & Hesketh, 1996; Leonard, McGregor & Allen, 1992; Oetting, Rice & Swank, 1995; and Leonard, Eyer, Bedore & Grela, 1997) or participants whose intelligibility is affected by phonological impairments (Frazier Norbury, Bishop & Briscoe, 2002), or participants who did not meet cut-off criteria on a standardized articulation test (e.g. Montgomery, 2000a, 2002a).

It is worrying that there appears to be a double standard in excluding phonological disorder. For the above investigators, it was important to exclude children with specific errors or unintelligible speech because of the potential effects on their test results. It should immediately be evident that their samples would not be representative of a typical SLI population, many of whom will have

sound errors, which leads to questions regarding the generalisability of their results, particularly since studies regarding the receptive abilities of preschoolers with SLI have not used the same exclusionary criterion.

A second and crucial consideration is that studies on preschoolers tend to exclude children with phonological disorder, while studies on older children do not exclude children with a *history* of phonological disorder. The logical conclusion is that participants included in most studies of preschoolers, reflect a particular subgroup of children with SLI – those without a severe phonological disorder. Studies on school aged children may include children with a previous history of phonological disorder, which has probably been resolved by the time of the study (Law, Boyle, Harris, Harkness & Nye, 2000). Thus these two groups of studies (preschoolers vs school age) may not be comparable, as different subtypes of SLI were studied.

Oral Structure and Function

Any overt physical, sensory or motor deficits which could influence speech or language development and which would be detected in a broad screening assessment were excluded in the current study, that is obvious structural defects such as cleft palate and neurological deficits such as cerebral palsy were excluded. One of the hypotheses of this study is that children with SLI may have subtle abnormalities of oral function which will not be detected in the broad screening measures used in most previous studies. Abnormal oral structures or problems in oral function which may affect normal language production have to be excluded before SLI can be diagnosed (Leonard, 1998). However, no guidelines are provided to determine what is regarded as abnormal, leading to substantial differences among researchers in applying this criterion.

Stark and Tallal (1981a) probably provided the most detailed description of this criterion, specifying the absence of speech motor deficits as determined by a standard oral peripheral examination by a speech-language pathologist, as well as the absence of obvious peripheral motor or sensory deficits, or oral facial anomalies. They also recommended a screening test of 2-point discrimination on the tongue. Few other investigators have been as rigorous.

Some investigators do not mention this criterion at all (e.g. Gillam & Carlile, 1997; Gray, Plante, Vance & Henrichsen, 1999; Johnson et al, 1999; Hammer, Tomblin, Zhang & Weiss, 2001). Some investigators indicate that participants had normal oral structure and function without indicating how this was evaluated (e.g. Leonard, Eyer, Bedore & Grela, 1997; Kaderavek & Sulzby, 2000). Other investigators focus on structural aspects, and do not mention functional deficits (e.g. Bishop, 1992; Aram, Morris & Hall, 1993). A study by Flax et al (2003) appears to be the exception in terms of attention paid to this criterion, as they specified the absence of motor impairments or oral structural deviations that could affect speech or nonspeech movement of the articulators, but did not indicate how this was measured.

Investigators who have reported using a standard assessment instrument, cite the oral examination checklist by Robbins and Klee (1987) (e.g. Leonard, 1998; Montgomery, 2000a). This motor speech examination for children recognizes the maturational aspects of the nervous system and provides normative data on children aged 2.6-6.6 years (Love, 2000), thus would not be appropriate for older children. It assesses both the structure and function of the vocal tract from the lips to the respiration-laryngeal complex, and assesses both speech and nonspeech aspects. A cranial motor nerve format is used to organize the information on structure and function, permitting differential diagnosis of speech production subsystems. Love (2000) suggested this protocol provides more accurate and standardized assessment of the oropharyngeal mechanism in childhood dysarthrics and suspected developmental verbal dyspraxics than do other available tests. Consequently, the Robbins-Klee protocol may be more applicable to children with overt neurological dysfunction, than children with subtle deficits.

The Robbins and Klee instrument serves a useful purpose as a screening tool to exclude dysarthria and apraxia of speech, but is by no means likely to identify the oral function deficits hypothesized to be typical of children with SLI. For the purposes of this study a comprehensive checklist was compiled to assess a wide range of oral structure and functional aspects.

Frank Neurological Disabilities

Participants could not present with gross neurological deficits such as cerebral palsy, focal brain lesions, traumatic brain injury, or seizure disorders, nor could they currently be on medication for control of seizures, as established by parent report. Such neurological deficits would preclude the child from being diagnosed as having SLI (Stark & Tallal, 1981a; Leonard, 1998), or from being regarded as typically developing. The above mentioned neurological deficits may also affect speech production. Mild neuromaturational delays or attention deficits were not regarded as an exclusionary criterion, as Leonard (1998) pointed out that such deficits are common in the SLI population.

There is much variability in the literature regarding the application of the neurological criterion, suggesting that the literature on SLI does not reflect a neurologically homogenous group. Some investigators have kept to the strict guideline described above (e.g. Leonard, McGregor & Allen, 1992; Leonard, Eyer, Bedore & Grela, 1997; Kaderavek & Sulzby, 2000; Flax et al, 2003). Other investigators have softened the criterion regarding seizure disorders, by excluding uncontrolled seizures, or multiple or high dosages of anticonvulsants (e.g. Aram, Morris & Hall, 1993). Some investigators have not specified their neurological criterion (e.g. Bishop. 1992; Fujiki, Brinton & Todd, 1996; Tomblin, Records, Buckwalter, Zhang, Smith & O'Brien, 1997; Miranda, McCabe & Bliss, 1998; Tomblin & Buckwalter, 1998; Gray, Plante, Vance & Henrichsen, 1999; Johnson et al, 1999; Frazier Norbury, Bishop & Briscoe, 2002), or have given a broad criterion of no gross/frank neurological impairment (e.g. Gillam & Carlile, 1997; Montgomery, 2000a, 2002a). Other authors have excluded cerebral palsy and severe head injury, but did not comment on seizure disorders (e.g. Hammer, Tomblin, Zhang & Weiss, 2001).

Children with Attention Deficit (Hyperactivity) Disorder (AD[H]D) were not excluded from the study for two reasons. Firstly, AD(H)D is not regarded as an exclusionary criterion for SLI; and secondly, AD(H)D was one of the risk factors investigated in this study. Some investigators have noted limitations in attention specifically in children with SLI (Leonard, 1998). Little is known about the effects of AD(H)D on speech production. In an exploratory study (Herr, 2005),

inconclusive results were found regarding the effects of Ritalin on children's performance on the Speech Assessment Battery used in this study. Similarly, contradictory findings have been reported regarding the effects of Ritalin on auditory processing tests (Keller & Tillery, 2002). Due to the fact that there is not a clear relationship between AD(H)D and speech production, or medication for AD(H)D and speech production, it was decided not to exclude participants with AD(H)D. The variable of AD(H)D and medication for AD(H)D was thus documented, but not controlled. As Keller and Tillery (2002) pointed out, since Ritalin improves sustained attention and decreases behaviours which may interfere with test-taking, children who have been prescribed stimulant medication for AD(H)D should follow their usual medication regime when seen for testing. This principle was followed in the current study.

Emotional Disturbance

This criterion was not considered in the current study. It is generally agreed that SLI could not be the result of primary emotional disturbance (Leonard, 1998), which would be of less relevance to an adolescent population. This criterion becomes somewhat complicated in adolescence, as emotional and behavioural disturbances are not unusual among children with language and learning difficulties. There is a co-occurrence rate of 50-70% of language impairment and socio-emotional behaviour disorders (Redmond & Rice, 1998), while children with language impairment are at increased risk for psychiatric disorders of all kinds (Beitchman & Brownlie, 1996). It was felt that an investigation into the emotional status of participants was beyond the scope of this study, as it would be difficult to differentiate primary from secondary emotional disturbance. Furthermore, emotional disturbance is not likely to affect speech in adolescence, and was therefore not felt to be relevant to this study.

Peripheral Hearing Loss

Exclusion of peripheral hearing loss is probably the only criterion for which there is substantial agreement regarding measurement. Most researchers use standard hearing screening procedures recommended by ASHA (1990) which involves a pure tone screening at 20dB at the frequencies 500, 1000, 2000 and 4000Hz in each ear (Leonard, 1998). This standard was also used in the current

study. Any hearing impairment may, firstly, have influenced a child's language and speech development, resulting in speech errors; and secondly, but, more importantly, may influence a child's performance on any of the tasks used in the current study which require imitation of verbal stimuli.

Otitis Media with Effusion

Children who have recently had otitis media with effusion should be excluded (Leonard, 1998), as there is still not complete certainty whether the periods of fluctuating conductive hearing loss associated with this disorder may impact on language acquisition. However, not all studies include this criterion. As the current study relied heavily on imitation as an elicitation method, it was felt to be important to include this criterion.

Restricted Social Interaction

Participants could not present with significant reciprocal social interaction deficits, or restricted interests and activities. These behaviours are characteristic of autism or pervasive developmental disorder as described in the DSM-IV (American Psychiatric Association, 1994), and would therefore preclude a child from being diagnosed as having SLI (Leonard, 1998), or from being regarded as typically developing.

While social interaction is commonly regarded as an important diagnostic criterion (Leonard, 1998), few researchers mention this criterion in their studies. Studies by Bishop and colleagues (e.g. Frazier Norbury, Bishop & Briscoe, 2002) have started using the Children's Communication Checklist (Bishop, 1998) to exclude autism and pervasive developmental disorders (PDD). Other authors have relied on DSM-IV criteria, without specifying how these were measured (e.g. Leonard, Eyer, Bedore & Grela, 1997).

5.1.3 Conclusions Regarding Definitional Criteria

From the above discussion, it is apparent that there is much variation amongst researchers regarding criteria used to operationalise the diagnosis of SLI. Such variation renders comparison among studies questionable and may explain some of the conflicting results obtained in various studies on SLI. It is clear that there are no clear guidelines for the identification of adolescents with SLI. From the

conflicting practises regarding the exclusion/inclusion of children with phonological output disorders, it is apparent that further research regarding phonological disorders in children with SLI is necessary. Furthermore, function of the articulatory mechanism has not been adequately considered in the majority of studies, while subtle motoric deficits could impact on speech output in any task requiring verbal output. Should it transpire that phonological disorders and subtle motoric deficits of the oral musculature are common, and possibly even part of the phenotype of certain subtypes of SLI, researchers will have to reconsider their approach to these areas in participant selection.

5.2 Development of the Speech Assessment Battery (SAB)

The development of an instrument to assess speech deficits in adolescents with SLI was influenced by a number of factors. Existing paediatric and adult assessment instruments were felt to be inappropriate, as these were designed for particular populations and would not be sensitive enough to detect the type of speech disorder targeted in the current study. Based on the preceding discussion in Chapters 2-4 it was felt that a test battery approach, consisting of tasks with high performance demands, would be most appropriate. Scoring of the test battery would have to involve more than a right/wrong distinction, but should also allow the researcher to investigate aspects such as efficiency and monitoring. In the following section the rationale for the selection of tasks and scoring guidelines will be discussed.

5.2.1 Rationale for Selection of Tasks

No single measure can adequately examine all parts of the complex process that is speech production (Haynes & Pindzola, 2004). Consequently, a test battery consisting of multiple tasks is required for an accurate assessment. The Speech Assessment Battery (SAB) consisted of speech tasks which were graded in complexity from single word tasks to tongue twisters.

Performance Demands

Only speech tasks placing high performance demands on participants were included with the hope of detecting subtle speech deficits in this adolescent group. The assumption was that participants with SLI would be able to perform simple

speech tasks under optimal conditions, but that their speech may break down when tasks became more demanding. Tomblin, Freese and Records (1992) suggested that preference should be given to tasks that place performance demands on participants to diagnose language disorders in adults with SLI, with the assumption that subtle language impairment will only be detected under demanding conditions. Lewis and Freebairn (1992) utilized a similar strategy to identify residual effects of childhood speech and language disorders in family members of children with phonologic disorders. In their study residual effects were seen in adults on measures (also used in the current study) that stress the speech production system, such as repetition of multisyllabic words, speech error phrases and nonsense words. Stackhouse (2000) reported similar results with a so-called "resolved" group, who obtained average scores on standard articulation tests, but still had residual speech difficulties when tested on specific speech output tasks such as repetition of real and nonwords and speech rate.

Performance demands were evaluated in terms of the following factors:

*Linguistic Complexity***:** Flipsen (2002) recommended the use of structured speech elicitation tasks to minimize the influences of language formulation on aspects such as speech rate. Stimuli were selected with syntactic or morphological structures which would not be challenging for school-aged children. It was assumed that even adolescents with SLI would not have difficulty coping with the syntactic load of the phrases and sentences used in the SAB. With the exception of the single word tasks, stimuli also contained simple vocabulary items, which would not challenge the participants' semantic knowledge. Tasks included single word tasks (no syntactic load, high semantic load) and phrases/sentences (low syntactic load, low semantic load) to control the linguistic load of stimuli. The assumption was that if SLI participants tended to perform worse on one task, but at levels equivalent to TD participants on other tasks, their errors on the SAB could possibly be attributed to linguistic or memory factors. However, if the participants with SLI performed worse than TD participants on all tasks, differences were likely to be due primarily to difficulties with speech production.

Contextual Factors: Tasks were also selected to manipulate the contextual factors identified by van der Merwe (1997) (as discussed in Chapter 4) which may

influence speech sensorimotor control. Specifically, all tasks involved complex phonological structure; all tasks were motorically complex, with the single word tasks and tongue twisters possibly being more motorically demanding; length of utterance was varied, from single words to sentences; and familiar versus unfamiliar utterances were considered, in that the nonsense words were unfamiliar to all participants and multisyllabic words may have contained unfamiliar vocabulary, while the phrases and sentences contained familiar words. Familiar words are thought to be less motorically complex (van der Merwe, 1997), while length of utterance also affects motoric complexity.

*Citation Tasks***:** The use of citation tasks ensures uniformity of stimuli across participants, thus facilitating comparison. Any assessment of speech should include citation tasks, and tasks requiring language formulation (Kent, 1997). Citation tasks were therefore selected consisting of words, phrases and sentences of increasing length and complexity, in order to examine the effect of phonetic complexity, linguistic complexity and length on articulatory performance (Strand & McCauley, 1999). These tasks introduced a greater degree of phonetic or linguistic complexity than the simple speech tasks evaluated on the Oral Motor Evaluation which was also used in this study. Citation tasks may be selected to target basic articulatory functions, or in the case of the current study, to observe interarticulatory coordination. The use of imitation as an assessment strategy has limitations, as individuals may produce stimuli better in imitation than in spontaneous speech, as the stimulus does not have to be generated from the individual's lexicon, and the phonological plan is not constrained by the individual's phonological-rule system (Dodd & McCormack, 1995).

Information Processing Demands: The theoretical framework underlying the selection of speech tasks was that of resource allocation within an information processing framework. The underlying assumption was that resource allocation would affect an individual's ability to manage speech output processes (particularly motor processes), especially as other processing demands increase. This study thus followed a similar viewpoint to the Demands and Capacities model (Adams, 1990 in Tetnowski, 1998), which is used to explain dysfluencies in speech output. This model proposes that whenever demands, such as linguistic

or motoric demands, exceed a person's internal capacity to speak fluently, dysfluencies occur. A similar view is expressed by the neuropsycholinguistic model (Perkins, 1991 in Tetnowski, 1998), which suggested that to speak fluently a person's cognitive, language, phonetic and motoric systems all needed to be in synchrony. A delay or disorder in any area has the potential to throw the entire language production system out of balance. This study proposes that when the demands described below exceed a person's capacity for well-formed speech output, speech errors and dysfluencies will occur. Excessive demands would therefore induce speech errors and dysfluencies even in typical speakers.

Consideration of Existing Speech Assessment Measures

The selection of tasks to assess speech was guided by the hypothesis that speech deficits in adolescents with SLI would not be readily apparent in spontaneous speech or on tests commonly used to assess children's speech. Most tests of children's speech primarily elicit monosyllabic words and or words of relatively simple syllable structure. The tests also tend to rely on words which are in the vocabulary of preschool children, which usually do not include words with complex articulatory sequences. Traditional tests are not effective in detecting inconsistent errors or errors which do not match predicted developmental patterns (Strand & McCauley, 1999). Furthermore, many standardised tests are criticised for lack of face validity, as they are based on the naming of pictured objects, while speech is connected and is composed of more than nouns (Smit, 2004). Most available tests of articulation are also not appropriate for use with adolescents as pictures are chosen to be of interest to children (Smit, 2004). It has been suggested that phonetically balanced reading passages would be appropriate for use with adolescents (Smit, 2004). However, in view of the literacy difficulties experienced by many adolescents with persistent SLI, this option was not appropriate.

Spontaneous speech samples were also not felt to be useful for this study, for a number of reasons. Firstly, it would be difficult to structure a task that elicited comparable words from the participants. Secondly, participants may choose to avoid words with complex articulatory sequences, particularly if they know they have difficulty with long or difficult words. Thirdly, the language difficulties

which are the defining feature of children with SLI, may preclude their use of the type of words which are difficult to articulate, as these words often refer to abstract or less common concepts.

Consequently, a test battery was constructed specifically for this study, consisting of some tasks used in previous research studies, and one novel task involving tongue twisters. Having considered the preceding discussion regarding the linguistic abilities of adolescents with SLI (Chapters 2 and 4) and factors affecting speech production (Chapter 4), a model of hypothesized task complexity was developed for the use of this battery with a group of adolescents with SLI.

Hypothesized Model of Task Complexity

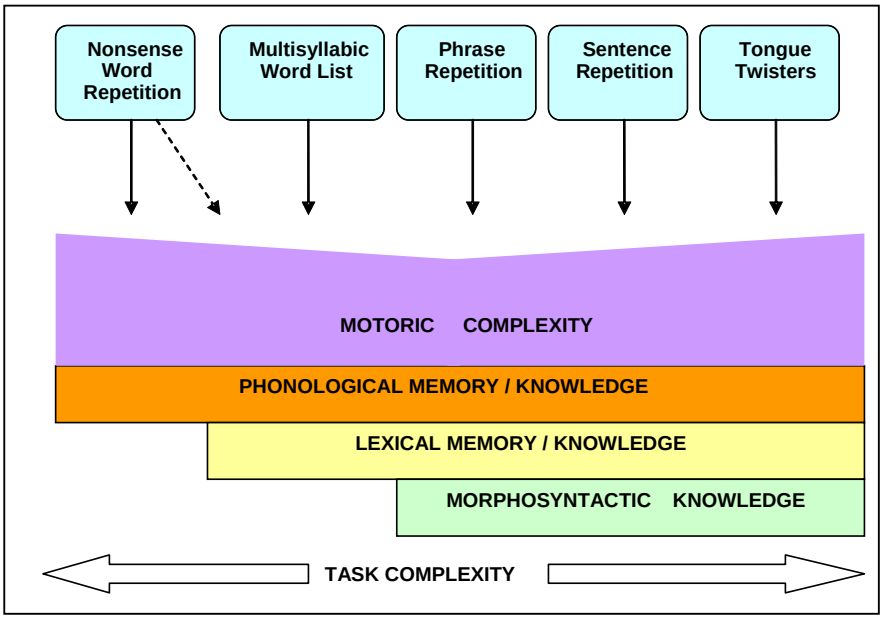

Figure 5-1: Hypothesized contribution of linguistic knowledge and motoric complexity to performance on Speech Assessment Battery (SAB) tasks.

Figure 5-1 reflects the hypothesized demands of each task. The model indicates that all tasks were motorically complex and required phonological knowledge and phonological memory. With the exception of the Nonsense Word Repetition task, all tasks involved lexical knowledge, although the impact of vocabulary knowledge on nonword repetition cannot be entirely excluded, hence the use of a dotted line. Single word tasks obviously required limited

morphosyntactic knowledge. Based on this model, it was assumed that the Phrase and Sentence Repetition tasks would be the easiest, as these tasks were the least complex in terms of motoric complexity and phonological knowledge required, while having substantial morphosyntactic and lexical support to facilitate the tasks. The Nonsense Word Repetition, Multisyllabic Word List and Tongue Twisters were hypothesized to be the most difficult: the single word tasks because of the reduced lexical support and the absence of morphosyntactic support; and the tongue twisters because of the very high motoric demands.

Table 5-1 provides a further summary of the hypothesized performance demands of the citations tasks included in the SAB, where "+" indicates that a variable is likely to have more impact; "-" indicates that a variable has less impact; and "+/-" indicates that the task may or may not be influenced substantially by that variable.

Phonological Complexity: The multisyllabic words and nonsense words were most complex phonologically, as they consisted of multiple syllables and many consonant blends. Only some phrases were phonologically complex. The sentences and tongue twisters contained some consonant blends, but words within the tasks were not necessary phonologically complex in terms of syllable structure. The latter two tasks contained words with sequences of similar consonants, which tend to be avoided or mispronounced by speakers (Taylor, 1990).

Motoric Complexity: All tasks were motorically complex in terms of the sound combinations involved, although the Phrase Repetition task did include items which were not motorically demanding.

Utterance length: Utterance length ranged from single words (which are theoretically easier to produce) to sentences. The Tongue Twister task contained the longest utterances, as each item had to be repeated five times, and was therefore likely to be the most difficult task in terms of length. It was important to include tasks involving connected speech (phrases and sentences). Connected speech requires more complex motor planning because of adjacent sounds in adjoining words that require rapid articulatory transitions; and the accommodation of the suprasegmental aspects of the utterance, such as intonation and loudness

contour, and durational variables (Smit, 2004). Furthermore, there is evidence to suggest that the major unit of planning in speech production is the clause (Field, 2004), thus single word tasks would not assess speech production fully.

Table 5-1: Performance demands of citation tasks in the Speech Assessment Battery (SAB).

	Multisyllabic Word List	Nonsense Word Repetition	Phrase Repetition	Sentence Repetition	Tongue Twisters
Phonological Complexity	+	+	+/-	+/-	+/-
Motoric Complexity	+	+	+/-	+	+
Utterance Length	-	-	+/-	+	+
Familiarity	+/-	-	+	+	+
Phonological Knowledge/ Memory	+	+	+	+	+
Morphosyntactic Knowledge	-	-	+	+	+
Lexical Memory/ Knowledge	+/-	-	+	+	+

Familiarity: Phrases, sentences and tongue twisters contained familiar words, which would be easier to produce. Some multisyllabic words may have been unfamiliar to participants, particularly the SLI participants with their vocabulary deficits, and hence more difficult to produce. Nonsense words were unfamiliar, and would therefore be most difficult to produce, as the speaker would not have access to existing motor programs which form part of the lexical representation, but instead would have to create a new motor programme from a new phonological representation (Rees, 2002). It can therefore be assumed that repetition of nonsense words would be more demanding of resources than repetition of real words.

Phonological Memory: All the tasks were reliant on phonological memory in order to retrieve the correct phonological forms.

Morphosyntactic Knowledge: In repeating the single words, participants would not be able to use morphosyntactic knowledge to monitor the accuracy of responses, while they may have done so in the phrase, sentence and tongue twister tasks.

Lexical Knowledge: The Phrase and Sentence Repetition and Tongue Twister tasks involved simple vocabulary, hence the participants' lexical knowledge could aid feedback and self-correction in these tasks. The Multisyllabic Word List contained many low frequency vocabulary items, which may have been unfamiliar to some participants, particularly those with SLI. These participants would not have been able to use lexical knowledge to aid self-monitoring. Some nonsense words resembled known English words, thus lexical knowledge could have aided some participants. However, again, participants with poor vocabularies would not have been able to utilise lexical knowledge in the performance of this task.

The tasks thus varied with regard to their phonological and motoric complexity, length, familiarity and the effects of long term phonological, morphosyntactic and lexical knowledge. The purpose of each of the tasks included in the Speech Assessment Battery (SAB) will be discussed below, that is: The Multisyllabic Word List (MWL), Nonsense Word Repetition (NWR), Phrase Repetition (PR), Sentence Repetition (SR), and Tongue Twisters (TT). Detailed descriptions of each task and examples of stimuli are provided in Chapter 6.

Purpose of Tasks in the Speech Assessment Battery (SAB)

Multisyllabic Word List (MWL): The Multisyllabic Word List (Catts, 1986) aims to distinguish individuals with sound sequencing difficulties in single words. In previous studies the MWL did not correlate with measures of phonological awareness, suggesting that it measures different phonological processing skills, which are not dependent on phonological awareness (Kamhi & Catts, 1986). The MWL (or variations thereof) has been used to investigate differences between language and reading impaired children (Kamhi, Catts, Mauer, Apel, & Gentry, 1988), novel word learning in hearing impaired children (Gilbertson & Kamhi, 1995), and residual errors in adolescents and adults with a history of speech disorder (Lewis & Freebairn, 1992).

Nonsense Word Repetition (NWR): The Nonsense Word Repetition Task (Kamhi & Catts, 1986) assesses the ability to report unfamiliar sequences with a reliance on verbal short term memory, but differs from the nonword repetition task used to assess phonological memory, in that it includes words that are difficult to articulate. These words were therefore both phonologically and motorically complex, and were unfamiliar. The use of nonsense words would assess participants' ability to assemble and execute new motor programmes for unfamiliar words (Stackhouse, 2000). Kamhi, Catts, Mauer, Apel and Gentry (1988) originally proposed that this task assessed the encoding of phonological information. However, results of their study suggested that this task assesses the planning of complex phonological sequences rather than encoding, thus concurring with Stackhouse's viewpoint. This task was also included in the Lewis and Freebairn (1992) study on residual errors.

Phrase Repetition (PR): Speech Error Phrases (Catts, 1987 in Lewis & Freebairn, 1992) assess production of similar sound combinations in various syllable positions in short phrases. Phrases were judged to be short enough not to tax short term memory in adolescents, while providing contextual support in the form of syntactic and semantic factors. The words were phonologically less complex than the single word tasks, but remained fairly complex motorically. Words were familiar, while in terms of length, these stimuli were the shortest of the multi-word tasks. Hence, Phrase Repetition was hypothesized to be the easiest of the speech tasks. It was hypothesized that since the phrases were short, and well within the participants' memory span the role of short-term memory would be reduced. Similarly, since the phrases were simple in terms of syntactic and semantic load, the language deficits of the participants with SLI were less likely to impact on their repetition of these items. These phrases were thus regarded as undemanding in terms of memory and linguistic load, increasing the likelihood that errors were due primarily to speech production difficulties.

Sentence Repetition (SR): The Sentence Repetition task was included to assess similar sound combinations in various syllable positions in longer utterances than those contained in the PR task. SR stimuli only had to be repeated once, which differentiated this task from the Tongue Twister task which required repeated

reiteration. Words were not phonologically complex, but were motorically complex. Words were familiar, while utterances were longer than the Phrase Repetition task. This task was therefore structured to be more demanding than the PR task, but less demanding than the Tongue Twister task.

Tongue Twisters (TT): The Tongue Twister task assessed the production of similar sound combinations in a variety of syllable positions. Words were usually phonologically simple, but motorically complex. Items were familiar, while length was manipulated to increase from three to six words. Tongue twister paradigms involving repeated reiteration and combinations of highly similar phonemes (as in the current study) are reported to induce true prearticulatory encoding errors (Wilshire, 1999). The primary purpose of the tongue twister task was to assess speech production under demanding conditions. Tongue twisters are regarded as a promising research tool, as the phonological errors induced artificially by tongue twisters provide both quantitative and qualitative information which can be used to test a wide range of empirical questions (Wilshire, 1999). Tongue twisters have been used to demonstrate that combinations of similar phonemes increase the likelihood of error; that speech rate influences error; and that there are qualitative changes in errors with practice (Wilshire, 1999). Tongue twisters were thus selected to induce high error rates. The alternation of initial phoneme clusters, as occurred in some of the items, is known to be particularly effective in slowing overt speech production and inducing overt speech errors involving perseverations or exchanges (Keller, Carpenter & Just, 2003). The use of similar phonemes in targets and repeated reiteration have been shown to have significant error-inducing effects (Wilshire, 1999), and were thus incorporated into the task.

It was anticipated that both the SLI and TD groups would find the Tongue Twister task challenging. However, as one of the hypotheses of this study was that participants with SLI could cope adequately with simple speech production tasks which are not resource-demanding, it was important to include a task which would be difficult even for unimpaired speakers. The question was not whether participants with SLI would find tongue twisters difficult, but whether they would find tongue twisters significantly more difficult than their TD peers.

5.2.2 Scoring of the Speech Assessment Battery (SAB)

The scoring guidelines for the repetition tasks were based on the hypotheses of this study, particularly the effects of resource allocation and linguistic ability on speech production. A simple right/wrong decision for each item, as was used by Kamhi and Catts (1986) and Lewis and Freebairn (1992) would not be sensitive to qualitative differences between groups, nor would it reflect differences in automaticity of responses or the amount of effort required to produce a correct response. For example, in the Kamhi and Catts study, or Wilshire's (1999) study on tongue twisters, participants were not penalized for false starts or dysfluencies. The scoring guidelines thus had to capture not just accuracy of the final product, but the number of attempts required to produce the final product, and the number of deviant behaviours and attempts at self-correction produced by each participant. This decision was in line with suggestions by Conti-Ramsden and Hesketh (2003), who suggested that detailed error analysis of nonword production presents interesting research possibilities in terms of comparing children with SLI to those with typical language development.

Traditional methods of analyzing speech errors in children were felt to be inappropriate with this adolescent population. The use of phonological process analysis or the traditional classification of articulation errors (sound substitution, omissions, distortions or additions) assumes that consistent patterns are evident in speech errors. However, as Kamhi, Catts, Mauer, Apel and Gentry (1988) reported, older children with language impairment do not display errors on specific speech segments. At the same time, assessments typically used with adults with speech disorders were also inappropriate, as these are usually designed to identify overt neurogenic disorders (dysarthria or apraxia of speech) or fluency disorders, rather than subtle, inconsistent speech errors which may be dependent on linguistic or phonological context. Other quantitative measures for segmental and suprasegmental analyses such as the Articulation Competence Index (ACI) or Percentage Consonants Correct (PCC) proposed by Shriberg (1993) could not be used, as these are derived from samples of spontaneous speech.

A decision had to be made regarding the use of terminology to describe errors. Terms could either be selected from the area of developmental

phonological disorders, or from literature on adult speech errors[27]. Since the study was focusing on speech production during development, it was decided to use developmental terms.

Analysis of deviant speech behaviours was based in part on Van der Merwe's (1997) and Caruso and Strand's (1999) models of speech production, as well as Levelt's and Dell's models of lexicalisation (described in Chapter 2). Table 5-2 below describes how the errors or deviant behaviours were classified, while Appendix J provides definitions for each category.

Selection for each of the categories can be justified as follows:

Sentence-level errors may reflect memory deficits (Word Omission) and errors in lemma retrieval (Semantic Word Substitutions). Since the tasks relied on imitation, few sentence-level errors were expected.

Sound substitution errors may reflect deviant segment-to-frame associations, in the form of sequencing errors (Transpositions) or sound substitutions. Substitution errors were further divided into errors influenced by phonetic context which resulted in meaningful words (Word Substitution [Phonemic]), suggesting the use of a postlexical editor, as opposed to substitution errors influenced by the phonetic context (Assimilations) which did not result in meaningful words; or errors which were not meaningful and could not be accounted for by phonetic context (Substitutions). Since coarticulation studies have shown that the effects of one sound on another can cross both word and syllable boundaries (Haynes & Pindzola, 2004), the identification of assimilation or word substitution (phonemic) errors considered the utterance as a whole, and not just individual words.

Changes to syllable structure in the form of Additions or sound Omissions may reflect an inability to sequentially organize a series of movements for a sequence of phonemes, but could also reflect incorrect construction of a syllable frame (Levelt, 1992).

[27] Examples of error types used to describe speech errors in normal adults include: exchange/transpositions/spoonerisms/metatheses, anticipation and perseveration (assimilation/ substitution), addition, and deletion/elision/omission (e.g. van den Broecke & Goldstein, 1980; Taylor, 1990; Meijer, 1997; Wilshire, 1999); while terms such as paraphasias and neologisms are preferred when discussing speech errors of neurogenic origin (e.g. Gordon, 2003).

Distortion errors could reflect deficits in articulatory timing and positioning (Caruso & Strand, 1999).

Fluency errors: Hesitations and Prolongations may provide evidence of feedback and feedforward mechanisms (van der Merwe, 1997), reflecting self-monitoring; or reflect the influence of the central executive in managing slower processing resources. Hence Hesitations could reflect either an attempt to self-correct an error before it occurs, or additional planning time necessitated by slower processing. It has also been suggested that such hesitations could be linked to the planning stages of speech (Garman, 1990) and concentration (Field, 2004). In some instances Hesitations may reflect difficulty in initiating movement, while Prolongations may reflect either poor articulatory timing or difficulty in initiating the next movement required.

Table 5-2: Analysis of speech errors or deviant speech behaviours with reference to theoretical models.

Stage of speech production		Category	Sub-categories	Potential Influences
Cognitive-linguistic planning Concept Lemma		*Sentence-level errors*	Word omission Word substitution (semantic)	Linguistic knowledge and memory.
Lexeme	Syllable frames	*Changes to syllable structure*	Addition Omission (sound)	Postlexical editor. Rate of activation decay. Phonotactic constraints. Frequency bias. Length effect.
	Segmental information	*Sound substitution errors*	Assimilation Word substitution (phonemic) Transposition Substitution	
Sensorimotor planning		*Distortion*		Mental syllabary / Core motor plans.
Sensorimotor programming		*Fluency errors*	Hesitation Prolongation	Planning. Monitoring. Motoric deficits.
Execution		*Not applicable*		
Feedback/ Feedforward OR Phonemic Representation		*Repetitions/ Revisions*	Sound/part-word repetition Word repetition Phrase repetition Revision	Control processes.
Awareness of performance		*Interjections* *No Response*		

Repetitions/Revisions may reflect that the participant is monitoring his/her speech output either through auditory or proprioceptive feedback. If he/she is dissatisfied with the output produced, Repetitions and Revisions may reflect the participant's attempts to improve the output. Revisions may reflect attempts to correct errors which have already occurred (feedback), while Repetitions may reflect that the participant anticipates producing an error, and thus revises the motor plan or motor program as required (feedforward). Repetitions and Revisions have also been associated with planning (particularly revisions at the beginning of utterances) or with constituent assembly (Garman, 1990). Alternatively, Kohn and Smith (1994) proposed that word fragments are typical of breakdown at the phonemic representation level, where only part of the representation is submitted to the articulatory program.

The inclusion of the Fluency errors and Repetitions/Revisions derives in part from literature on stuttering where some theories explain stuttering in relation to capacity. If a speaker's capabilities are exceeded, fluency breakdowns occur (Tetnowski, 1998). The suggestion is that motor speech is affected by stress on any part of the language-processing system. The neurolinguistic model of fluency (Perkins et al, 1991 in Tetnowski, 1998) in particular highlights the need for synchrony between the cognitive, linguistic, phonetic and motor systems for speech, suggesting that delay or disorder in any of these areas can affect fluency. Children with SLI are suspected to have a higher incidence of motoric deficits and are known to have language deficits, hence there is the potential for dysfluencies to occur in this population.

Awareness of performance: Participants may demonstrate awareness of their own performance by refusing to repeat items which are perceived as difficult, or requesting repetition of items when they experience difficulty (No Response). Some participants may also comment on their own performance (e.g. this is really hard) or use fillers (e.g. um) while repeating items (Interjections). The use of interjections tends to increase with age (Enger, Hood & Shulman, 1988), but in this study, which relied primarily on speech repetition tasks, it was not anticipated that interjections would occur with great frequency.

In view of the types of errors reported on these types of tasks, as well as clinical experience with adolescents with SLI, it was anticipated that substitution errors would be more frequent than changes to syllable structure. Based on clinical experience, few distortion errors were expected. Fluency errors and repetitions and revisions were expected to be common, in view of previous findings regarding breakdowns in these areas with increased discourse demands.

Tasks were therefore scored in terms of accuracy, but all deviations from the stimulus provided were also noted and were included in the scores obtained. A detailed description of scoring guidelines is provided in Chapter 6.

5.2.3 Conclusions Regarding the Development of the SAB

The SAB involved a battery of citation tasks designed to make high performance demands of the speech output system, with the expectation that such tasks would increase the likelihood of inconsistent, context-dependent errors. In view of the aims of the study, all tasks were motorically and phonologically demanding in an attempt to increase speech errors, while linguistic and memory demands were varied among the tasks in order to separate linguistic variables from speech output variables. Scoring guidelines allowed for a greater depth of analysis than in previous studies using these or similar tasks, and allowed for inferences regarding the efficiency or automaticity of speech production during these tasks, thus allowing results to be interpreted within an information processing model.

5.3 Significance: Clinical and Research Considerations

As discussed in Chapter 1, there should be an interplay between research and clinical work. As Rutter (2005) stated, research ideas often arise from clinical observations (as was the case in the current study), but it is also necessary to test out research findings in clinical practice. Rutter further suggested that in order for research to be of value to clients, research findings should be used to develop better methods of client care and treatment. It was therefore hoped that results of the current study would not just add to a body of theoretical knowledge, but would be useful to clinicians. Adopting such a clinical perspective suggested that findings should have not only research or statistical significance, but also clinical

significance. Consequently, results obtained in this study were analysed on an additional level, motivated by the researcher's viewpoint as a clinician.

At this point it is appropriate to consider issues surrounding clinical and research significance, particularly with reference to the results obtained on the Speech Assessment Battery devised for this study. The term "clinical significance" is generally used to refer to measurements of treatment efficacy or change. In this context, "…'clinical significance' refers to whether a treatment that meets scientific standards for effecting behaviour change is also significant in a clinically or socially relevant way…reflect(ing) *important* and *acceptable* changes in behaviour" (Goldstein, 1990, p.91). This definition was adapted for the current study which looked at differences in speech production between typically developing adolescents and adolescents with SLI, to refer to important and clinically relevant differences in scores obtained by the two groups.

Different criteria are used to determine statistical and clinical significance. As Johnson, Dow, Lynch and Hermann (2006) proposed, statistical null hypothesis testing approaches are limited in their clinical relevance and practical utility for rehabilitation professionals. One of the difficulties in applying results regarding statistical significance to clinical populations, is that statistically significant differences may reflect moderate differences between all the participants in both groups; or may reflect large differences in a subset of participants and no differences in others (Goldstein, 1990). For example, tests of nonword repetition represent one such task, where clear differences have been demonstrated with regard to mean scores between children with SLI and typically developing children. However, inspection of individual scores indicates that there is often much overlap between the two groups, with some SLI participants obtaining high scores, and some typically developing participants obtaining low scores (e.g. Montgomery, 1995; Adams & Gathercole, 1995; Edwards & Lahey, 1998; Botting & Conti-Ramsden, 2001). Data analysis within our discipline should reflect not only whether associations between variables or differences among groups/individuals exist, but whether these associations or differences are of practical importance (McCartney & Rosenthal, 2000)

In order to deal with such difficulties, the study adopted the following approaches in its design (see Chapter 6) and the analysis of results (see Chapter 7):

- Firstly, in order to determine whether differences between groups were important and socially relevant, caregivers were asked specific questions regarding the participants' speech abilities. If, in addition to possible statistical differences between groups, caregivers were to identify speech deficits/differences in participants with SLI more frequently than in typically developing participants, results could be regarded as clinically significant.
- Secondly, normative comparison data offer a viable approach to assessing the degree to which results are clinically significant (Goldstein, 1990), hence participants with SLI were compared to age-matched peers without communication disorders.
- Thirdly, as Goldstein (1990) reported, in group designs it is acceptable to report differences between group means, but it would also be useful to report the percentage of individuals who present with clinically significant differences. This study thus aimed to identify a Poor Speech Group, which obtained scores substantially poorer (at least 2*SD* below the mean) than that of the typically developing group.
- Fourthly, a consideration of clinical significance allows one to bridge research and clinical practice by focusing on individual rather than group differences (Johnson, Dow, Lynch & Hermann, 2006). As Johnson et al (2006, p.37) emphasized: "Professional practice hinges on attention to individual outcomes, which makes the analysis of differences between group means dubious." Accordingly, scattergrams of individual results in each group were also considered in order to determine if statistically significant differences applied to all participants in the group with SLI.
- Finally, small differences between groups may be statistically reliable, but they have less significance for the clinician (Johnson, Dow, Lynch & Hermann, 2006). Thus the absolute magnitude of scores obtained on the SAB were considered, using clinical judgement, to determine if the differences were clinically significant. Accordingly, results obtained on some subtests

were regarded as more important than others, based on whether the differences in scores were judged to be acceptable and important on a clinical level. Tasks which yielded small differences when looking at absolute scores (even if statistical differences were significant) were therefore accorded less importance in the discussion in Chapter 7, as these tasks would be of less significance clinically.

Effect sizes were not considered in the current study. Although this method assesses magnitude, it does not directly assess clinical significance (McAweeney & Crewe, 2000), and even large effect sizes may not be clinically relevant (Jacobson, Roberts, Berns & McGlinchey, 1999). It was felt that the procedures discussed above would provide a better index of clinical significance. Such a decision is in line with advice offered by Jacob Cohen (1990, p. 1304), the well-known author in the area of statistical analysis, that "…there is no royal road to statistical induction, that the informed judgment of the investigator is the crucial element in the interpretation of data."

5.4 Summary and Conclusions

In Chapters 2-4 methodological considerations from each area were highlighted. These considerations were taken into account in the design of this study. This chapter has elaborated these issues and embedded them into a framework, and has also provided an overview of the primary methodological and conceptual aspects of this study, by describing the criteria which were used for the selection of adolescent participants with SLI after a critical review of existing research practices in this regard. It also provided a rationale and theoretical justification for the development of the Speech Assessment Battery, the primary instrument used to gather data regarding speech deficits in this population. Finally, issues regarding research and clinical significance were discussed briefly to justify some of the decisions regarding the study's design and analysis of results. In the following chapter, the method used in this study is described.

6 Method

This chapter will describe the method used to investigate the hypotheses of this study. The aims and hypotheses of the study will be described, followed by a description of the chosen research design. Participants will be described in terms of the sampling procedure, selection criteria and selection procedures used. Thereafter the data collection process will be described with reference to pilot studies, instrumentation and procedures used. Finally, data analysis will be described. Ethical consideration will be highlighted throughout this chapter.

6.1 Aims

The primary aim of the study was to understand the nature of speech deficits in young adolescents with Specific Language Impairment (SLI). Accordingly, the study aimed to investigate and explain the presence of speech production errors in adolescents with SLI. To date there has been limited investigation into the nature of SLI in adolescence, and even less investigation into speech production in SLI, particularly beyond the preschool years. The following sub-aims were formulated:

- To determine if young adolescents with SLI present with inconsistent residual speech errors when producing phonologically complex utterances of low syntactic and semantic load. Specifically, the study compared the speech production of adolescents with SLI on graded speech citation tasks with that of typically developing adolescents; and investigated relationships between performance on language and memory tasks and speech production tasks.
- To determine if adolescents with SLI present with subtle neuromotor deficits that could impact on speech production. Specifically, the study aimed to determine a) if young adolescents with SLI present with functional abnormalities of the articulators, independent of linguistic factors; and b) if participants had a history of motor deficits in non-speech domains.
- To determine if speech production deficits are a common feature of the phenotype of young adolescents with persistent SLI. The study thus aimed to determine if the Speech Assessment Battery (SAB) is a useful index to assist in diagnosis of SLI i.e. ruling in or ruling out SLI based on SAB scores.

- To perform a preliminary investigation into the possible etiology of speech deficits in adolescents with persistent SLI by identifying risk factors associated with poor speech production in this population. Specifically, the risk factors present in a Poor Speech subgroup of the SLI group were compared to that of the TD group and the SLI group as a whole.

6.2 Hypotheses

Three primary hypotheses emerged from the preceding discussion regarding: a) the nature of SLI, b) the etiology of SLI and speech disorders, and c) the continuum of development from childhood to adulthood.

6.2.1 Hypotheses Regarding the Nature of SLI

- Speech deficits are a characteristic component of SLI, thus adolescents with SLI will present with a higher frequency of speech errors than typically developing adolescents.
- Speech deficits, which are not unusual in preschool children with SLI, do not necessarily resolve, but remain in the form of inconsistent residual errors in adolescence and adulthood. Adolescents with SLI will thus present with a higher frequency of inconsistent speech errors than typically developing peers.
- Increased resource demands within the information processing system, specifically complexity of phonological structures, will affect speech performance in terms of the frequency of speech errors. More errors are likely to occur on tasks involving multisyllabic low-frequency words or nonwords, where there is the absence of semantic and syntactic support in the presence of complex phonological structures. Tongue twisters are likely to elicit a high number of inconsistent errors, in view of the phonological complexity and demands on temporal coordination. Repetition of phrases and sentences will elicit fewer errors, as syntactic and semantic cues are present to facilitate self-monitoring.
- In view of the complex interactions among language, speech and memory, performance on speech tasks correlate with performance on memory and language tasks.

6.2.2 Hypotheses Regarding the Origin of Speech Errors in SLI

- Many children with SLI have subtle neurological deficits affecting the motor domain, which may impact on speech production. Adolescents with SLI are thus more likely to present with a history of motor incoordination deficits, as well as a poorer performance on tasks evaluating the function of the articulators, than typically developing peers.
- Such neurological deficits are likely to have a multi-factorial origin, involving a combination of genetic factors, pre- and perinatal risk factors, and the co-occurrence of other neurodevelopmental deficits, such as AD(H)D. Adolescents with SLI and with a high frequency of speech errors are thus more likely to have a history of genetic, pre- and perinatal risk factors and AD(H)D.

6.2.3 Hypothesis Regarding the Continuum of Development from Childhood to Adulthood

- It is possible to detect residual, inconsistent speech errors easily in early adolescence, which represents a midpoint in motor speech development between the developmental speech errors of early childhood and the full competence of adults.

6.3 Research Design

This explanatory study employed a nonexperimental, quantitative group design. The study aimed to describe differences between groups without manipulating any variables and was thus nonexperimental in nature (Pedhazur & Pedhazur Schmelkin, 1991). Two groups were formed, on the basis of the dependent variable, diagnosis of SLI. A between-subjects comparison or a standard-group comparison was selected. Although a group design was used, generality of findings to other groups and settings can only be demonstrated through replication.

A quantitative approach was selected as it places priority on studying differences between groups, as opposed to qualitative research which emphasizes similarities between groups (Sarantakos, 1998). As the reliability level of quantitative data is a function of the interaction between the observer and the observed (Silverman, 1993), participant selection and testing procedures were planned and evaluated carefully.

An *ex post facto* design studies causation by an analysis of past events (Silverman, 1993). In this study the participants' early history, family history, history of motor deficits, and history of phonological disorders, as reported in a parent questionnaire were related to their current performance on speech tasks. As no independent variable is manipulated, retrospective studies cannot establish a direct relationship between presumed cause and effect (Hegde, 1987). However, in view of the age group chosen for this study, it was difficult to obtain objective reports on the participants' early speech abilities. Within this cross-sectional study there was thus no choice but to rely on parent accounts, which is a limitation of the study. This study could merely suggest variables that may be verified through other means of investigation (Hegde, 1987).

6.4 Participants

6.4.1 Sampling Procedure

This study employed nonprobability, purposive sampling, as the study was of limited scope and precluded random selection (Sarantakos, 1998; Singleton, Straits & Straits, 1993). A disadvantage of purposive sampling is the fact that informed selection of cases requires considerable knowledge of the population before the sample is drawn. However, as discussed previously, in the area of SLI guidelines have been provided by several researchers for the selection of participants (e.g. Stark & Tallal, 1981a; Kamhi, 1998; Leonard, 1998; Plante, 1998).

The study included two groups: A group of adolescents with Specific Language Impairment (SLI), and a group of age-matched peers with typical language development. Groups were matched on age rather than speech or language ability, as the adolescent SLI population is so poorly described. It is advisable in nonexperimental research to obtain samples of equal size because of consideration of statistical analyses (Pedhazur & Schmelkin, 1991). Thus, each group consisted of 31 participants. Since nonprobability sampling was used, representativeness and generalizations are related to quality rather than quantity of participants (Sarantakos, 1998). Hence, in view of the difficulty of finding

participants who match strict research criteria for SLI, fairly small groups were selected.

6.4.2 Participant Selection Criteria

Participant selection criteria are summarized in Table 6-1.

Table 6-1: Participant selection criteria.

		SLI	TD
General Criteria	**Age**	13.0-14.0 years	
	Home Language	English	
	Race	No restriction	
	Gender	Equivalent number of males and females	
	Socioeconomic Status	Similar geographic area. No marked socioeconomic disadvantage.	
Language	**Language Status**	Diagnosis of SLI by SLP*. Scaled scores -1.3*SD* below mean for age on two language measures.	No history of language or learning impairment. Above 60% for language and literacy areas on last report.
	History of Speech-Language Therapy	Included	Excluded
Exclusionary Criteria	**Intelligence**	Nonverbal IQ over 80.	No grade retention. Placement in ordinary school.
	Neurological Status	Exclude cerebral palsy, focal brain lesions, traumatic brain injury and seizure disorders, as well as medication for seizures.	
	Speech	Exclude voice and fluency disorders.	
	Oral Structure and Function	Exclude marked abnormalities of oral structure and function.	
	Hearing	Pass pure tone screening at 20dBHL at 500Hz, 1000Hz, 2000Hz and 4000Hz.	
	Otitis media with effusion (OM-E)	No OM-E in last six months.	
	Social interaction	No restrictions of social interaction.	

** SLP refers to a speech-language pathologist.*

General Selection Criteria

All participants had to meet the following general criteria:

Age: Participants had to be between the ages of 13 years 0 months and 14 years 0 months. A relatively small age range was chosen as motor speech abilities and language continue to develop during the adolescent years, and confounding factors due to development had to be controlled. By this age participants would have completed their phonetic inventories, so that speech errors could not be

attributed to incomplete speech sound development, as would be the case with younger participants. Participants would also be in the late stage of motor speech development (Kent, 1999) so that physical changes to the articulators would have a smaller effect on speech production. However, their motor speech abilities would not have reached full maturity, thus demonstrating the effects of an immature neurological system on speech production.

Home Language: Participants were required to speak English as their home language and language of education, to exclude the effects of second language acquisition on the children's performance on the test batteries.

Race: Race was not considered in selecting participants. Epidemiological studies have indicated that race per se does not appear to be related to the prevalence of SLI (Tomblin, Records, et al, 1997).

Gender: Each group consisted of equivalent numbers of boys and girls. Sex differences, which are evident in the biomechanical maturation of the speech production mechanism (Kent, 1999) could potentially influence results on the speech assessment battery, as was found by Flipsen, Shriberg, Weismer, Karlsson and McSweeny (1999) in their study on the acoustic properties of /s/ in older children and adolescents.

Socioeconomic Status: All the children attended schools and resided in a similar geographic area. While socioeconomic status was not strictly controlled, none of the participants came from a disadvantaged background.

Diagnosis of SLI

It was important to consider the selection criteria carefully, as participant selection is one of the major approaches to control in nonexperimental research (Pedhazur & Pedhazur Schmelkin, 1991). Furthermore, one possible threat to the internal validity of a between-subjects design is selection bias.[28] To ensure accurate sampling, participants with SLI had to meet certain diagnostic criteria. As discussed in chapter 5, the following inclusionary and discrepancy criteria were used for the current study:

[28] Selection bias refers to any systematic differences between the groups, other than the variable (SLI) used to allocate participants to comparison groups (Neale & Liebert, 1986).

- The participants had to obtain scaled scores below 80 on at least two language measures during the previous two years. For most participants the standardized tests included the Test of Language Development–Intermediate (TOLD-I) (Hammill & Newcomer, 1982) or Clinical Evaluation of Language Fundamentals–Revised (CELF-R) (Semel, Wiig & Secord, 1997). Results from a single language test were used to identify participants with SLI, provided that the test consisted of a number of subtests, evaluating both receptive and expressive language, and at least morphosyntax and semantics.
- The cut-off for language scores was set at 1.3*SD* below the mean for the participant's age.
- The cut-off for nonverbal IQ was set at 80 or above on an individual intelligence test in the past. For all participants, IQ test scores obtained within the last three years were available.
- Participants should not currently be placed in an educational setting which caters for children with cognitive deficits.
- A clinical diagnosis of language impairment by the participant's speech-language pathologist was required for inclusion in the study.

Exclusionary Criteria

Both participants with SLI and typically developing (TD) participants had to meet the following exclusionary criteria:

- Children with previously diagnosed speech disorders other than phonological disorders were not included in the study. Thus children with known fluency and voice disorders were excluded from the study. Children who presented with dental abnormalities, causing consistent phoneme distortions were not excluded. Similarly, children presenting with tongue thrust leading to anterior production of alveolar sounds, were not excluded. The current study elected not to exclude children with phonological disorders, provided the participants also had a language disorder.
- Any physical, sensory or motor deficits which could influence speech or language development were excluded based on learner files and the Oral Motor Evaluation used in the study. This criterion included any noticeable oral structural or

functional abnormalities (Leonard, 1998), such as cleft palate or tongue malformations. As a detailed checklist regarding oral structure and function formed part of the instrumentation for this study, no screening was conducted as part of the selection criteria.

- Participants could not present with gross neurological deficits such as cerebral palsy, focal brain lesions, traumatic brain injury, or seizure disorders, nor could they currently be on medication for control of seizures, as established by parent report.
- Children with Attention Deficit (Hyperactivity) Disorder (ADHD) were not excluded from the study.
- Participants were required to have hearing within normal limits, as determined by parental report and hearing screening tests performed by their school. Standard hearing screening procedures recommended by ASHA (1990), involving a pure tone screening at 20dB at the frequencies 500, 1000, 2000 and 4000Hz in each ear (Leonard, 1998) was used by clinicians whose files were accessed to determine if participants met the criteria for the current study.
- Participants should not have had any recent episodes of otitis media with effusion (as established by parent report).
- Participants should not present with significant reciprocal social interaction deficits or restricted interests and activities as reported by their parents and assessment reports by psychologists and/or speech-language pathologists.

Therapy

In view of the participants' age, it was likely that all the participants with SLI would have received speech-language therapy and/or other intervention at some point. It was thus not practical to exclude children who had received speech-language intervention. In fact, some studies have used history of therapy attendance as a diagnostic criterion for SLI (e.g. Bishop, 1992). As a result, it was decided not to control for the variable of therapy attendance, but to document this variable as far as possible using the risk factor form (see Appendix C), with particular emphasis on a history of therapy directed at speech production.

Participants with typical language development had no history of speech-language therapy currently or in the past. An exception was made in the case of children who had received therapy specifically for tongue thrust. Only one such participant (N18) received speech therapy at age 6 years for a tongue thrust, while he had acquired all speech sounds by age 5 years.

Selection Criteria for Participants with Typical Language Development (TD)

In addition to the general, exclusionary and therapy criteria discussed above, participants with typical development could not have repeated a grade at any point in their school career, and should have completed all their schooling thus far in an ordinary school. In addition, their last school report had to indicate a mark of at least 60% for the language and literacy areas. These criteria were included to avoid the possibility of including children with subtle, previously undetected language disorders.

Selection Criteria for Schools

In order to ensure that participants were as homogeneous as possible in terms of sociodemographic variables, schools within the same geographic area in Johannesburg were selected. In order to control for socioeconomic status to some extent, approximately equal numbers of participants from each group attended government and private schools.

Typically developing participants were recruited from both private and government ordinary schools in this area. Participants with SLI were recruited in part from ordinary schools (n=7), but most were recruited from schools catering for Learners[29] with Special Educational Needs (LSEN), particularly schools catering for children with specific learning disabilities (n=24). Many children with SLI develop reading and writing difficulties which persist into adolescence (Butler & Silliman, 2002), and in follow-up studies of children with SLI, it was found that by age 15 years, a high proportion of them were receiving special education, either supplementary to mainstream placement or in a special school (Stothard, Snowling, Bishop, Chipchase & Kaplan, 1998). It was thus expected

[29] In the South African educational system, pupils or students are referred to as "learners".

that many of these children would have been placed in LSEN schools[30]. The sample may therefore have been somewhat biased, in that most of the participants with SLI would have to present with substantial language and learning deficits to be placed in an LSEN school. The group of SLI participants may therefore not have been representative of an SLI population with milder language deficits.

6.4.3 Participant Selection Procedure

The proposal for the study was submitted to the University Ethics Committee for Research on Human Subjects (Medical). The study was approved unconditionally (Protocol No: M030808) (See Appendix A).

Principals of relevant schools were contacted to obtain permission to recruit participants. The study was discussed verbally with each principal and an information letter was provided (see Appendix B). The letter outlined the purpose and the value of the study; what they were asked to do; and identified possible benefits (Silverman, 1993). If they agreed to the study, written consent was obtained. Seven schools in the relevant geographic area were approached, but two principals did not give consent for the study. Table 6-2 below provides a description of the participating schools.

Table 6-2: Description of participating schools.

School	Area	Type	Number of Participants
School A	Blairgowrie	GDE: LSEN	16
School B	Victory Park	Private: LSEN	4
School C	Melrose	Private:LSEN	4
School D	Blairgowrie	GDE: Ordinary	29
School E	Victory Park	Private: Ordinary	9

Key:
LSEN: Learners with Special Educational Needs, specifically in this case, a school catering for children with specific learning disabilities.
GDE: Gauteng Department of Education, i.e. a government-funded school.

Testing was conducted over an 18-month period, thus all the schools, apart from School C, participated in the study in two consecutive years. Once the

[30] In South Africa inclusive education for children with special needs is still uncommon. In the socio-economic group used for this study, children with language and learning difficulties are likely to be referred for special class placement, which is only available before the age of 13 years, or special school placement. Participants in the current study with marked language and learning difficulties were thus likely to be placed in schools for Learners with Special Educational Needs.

principal consented to the study, staff members at the school were asked to identify candidates within the appropriate age range. Information letters were distributed to the parents or guardians of learners who met the age criterion (Appendix B), in order to invite parents and children to participate in the study. Attached to the information letter were a consent letter and a preliminary risk factor form, which would allow the researcher to determine if the child met the selection criteria outlined above. These forms were returned in a sealed envelope to the school for collection by the researcher, if parents or guardians agreed to allow their child to participate in the study.

Once parental consent was obtained, the learners' school files and copies of school reports were examined to determine if they met the IQ, hearing, language impairment and/or academic achievement criteria described above. Learners who met the selection criteria were contacted telephonically to arrange appointments for testing. Learners who did not meet the criteria were informed in writing why they did not meet the criteria for the study. If learners did not meet the criteria, but their parents were still interested in having them assessed, they were referred to the University Speech and Hearing Clinic at the University of the Witwatersrand or to private practitioners for testing.

On the day of testing, the study was explained verbally to the participants, using a written outline to ensure that all participants received the same information (see Appendix B). Participants were asked to sign this form if they assented to participate in the study.

6.4.4 Description of Participants

All the participants met the selection criteria specified above. A description of the participants is provided in

Table **6-3**, based on information obtained from school files and the detailed risk factor questionnaire.

Age: The TD participants were, on average, slightly younger than the participants with SLI, although both groups had a similar age range.

Gender: As is typical in the SLI population (Leonard, 1998), the sample consisted of more males than females (1.4:1). The TD group also consisted of

more males than females (1.2:1), in order to ensure that the groups were matched to some extent.

Race: The SLI group consisted of more white participants than the TD group. TD participants may have been more likely to be exposed to dialectal differences, as the South African Indian and Coloured communities speak dialects of English that differ slightly from mainstream South African English.

Schools: The majority of the participants with SLI were recruited from schools for learners with special educational needs. One of the participants currently attending an ordinary school, S16, previously attended a private school for children with learning difficulties, but was placed in an ordinary school 8 months before he participated in this study. Approximately 32% of the SLI group attended private schools. All the participants in the TD group attended ordinary schools, with only approximately 19% of the sample attending a private school.

Table 6-3: Summary description of participants.

		SLI	TD
School	**Ordinary Private**	n=2	n=6
	Ordinary GDE	n=5	n=25
	LSEN Private	n=8	-
	LSEN GDE	n=16	-
Age	**Mean**	13.44 years (*SD* 0.34)	13.33 years (*SD* 0.29)
	Range	13.0 – 14.0 years	13.0 – 14.0 years
Gender	**Male**	n=18	n=17
	Female	n=13	n=14
Race	**White**	n=28:	n=24
	Black	-	n=2
	Indian	n=1	n=4
	Coloured[31]	n=2	n=1
Significant Medical History		n=15	n=5
Speech-Language Therapy		n=29	n=1

While the two groups were relatively well-matched in terms of demographic factors, the group with typical language development may have been at a slight disadvantage in terms of age (younger mean age), socio-economic status (fewer attended private schools) and dialect (more TD participants were exposed to a non-standard dialect).

[31] In South Africa the term "Coloured" is used for people of a mixed ethnicity. This group has a unique cultural identity.

From the risk factor forms completed by caregivers (see Appendix C), the following information was obtained about participants[32]:

Medical History: Substantially more participants with SLI than TD participants reported significant medical factors. This finding is similar to that reported by Lahey and Edwards (1995) who found that children with a positive family history of SLI were more likely to have had at least one serious childhood illness or recurrent otitis media than children with a negative family history. The following significant medical factors were reported:

SLI Group	TD Group
Encephalitis (n=1)	Asthma (n=1)
Excessive appetite (n=1)	Diarrhea and vomiting (n=1)
Chicken pox (n=4)	Tonsillectomry (n=1)
Whooping cough (n=3)	Bronchialitis (n=1)
Severe diarrhoea requiring hospitalization (n=1)	Septic arthritis of the hip (n=1).
Allergies (n=2)	
Adrenal hypoplasia (n=1)	
Tonsillectomy and/or adenoidectomy (n=3)	
Myoglossal cyst (n=1)	
Operation to remove extra toe (n=1)	

Speech-Language Therapy: All participants with SLI reported a history of speech-language therapy. Four participants with SLI reported therapy directed specifically at speech errors. Only one TD participant reported attending speech-language therapy, for a tongue thrust.

6.5 Data Collection

6.5.1 Pre-Tests and Pilot Studies

Prior to data collection, two pre-tests and one pilot study were conducted to evaluate aspects of the data collection procedures. The overall purpose of the pilot study and pre-tests was to identify possible weaknesses, inadequacies, and problems in the research design (Sarantakos, 1998), so that these could be corrected before the main study took place.

The pre-tests and pilot study are described in full in Appendix D. A summary of the aims and conclusions are presented below.

[32] Two of the participants with SLI had been adopted, and could therefore not provide information about family history of related disorders, or, in one case, about early history.

Pre-Test 1: Recorded versus Live Voice Presentation of Stimuli

The first pre-test was conducted with a group of young adults who speak English as a first language, to determine if taped stimuli for the nonwords from the Children's Test of Nonword Repetition (Gathercole, 1995) and the Nonsense Word Repetition Task (Kamhi & Catts, 1986) were intelligible.

It was apparent that these typical young adults had great difficulty perceiving the taped stimuli. None of the participants obtained a score over 80%, and most of them made errors on at least a third of the words. Consequently, it was decided to use live presentation of stimuli, although this is acknowledged as a limitation of the study.

Pilot Study: Instruments and Instructions

Pilot studies were conducted on one participant with typical language development and three participants with SLI to determine if the test battery and procedures selected were appropriate and would meet the aims of the study. These participants were selected using the criteria and procedures described in 6.4.2 above, and were not included in the main study.

After the pilot study, the following recommendations were made regarding the test batteries and the data collection procedures:

- Testing could be conducted in a single session, although participants may have to be given short breaks during testing.
- Instructions were largely adequate. Elicitation of the Tongue Twister and narrative discourse tasks was adapted.
- Most of the speech assessment tasks included in the preliminary test battery were found to be sensitive to speech production deficits in this population. The exception was the Counting Task, which was excluded from the assessment battery because of lack of sensitivity. As the Speech Assessment Battery is heavily reliant on imitation responses, it was decided to devise a naming task to elicit complex articulatory sequences, and to administer the task to the first group of participants, in order to determine its usefulness.
- The list of categories used to classify speech errors was modified and expanded.

- The memory test battery was found to be adequate, and remained unchanged. The language test battery was adapted, with some tests being replaced due to lack of sensitivity.
- The risk factor questionnaire did not require modification. It was decided to introduce a third method of obtaining risk factor information, i.e. a telephonic interview with parents who did not return the initial risk factor questionnaire.

Pre-Test 2: Repetition versus Naming/Delayed Imitation Responses

The speech tasks used in this study were primarily reliant on repetition responses. As repetition is not an optimal elicitation technique, the second pre-test was administered to participants in the study to determine if at least one naming task could be included in the test battery, which would reduce reliance on short term memory. This was not a true pre-test, as the naming task was administered to the first group of 29 participants during the course of data collection, rather than prior to data collection.

The pre-test thus tried to determine if multisyllabic words with complex articulatory patterns could be elicited using a naming or delayed imitation task. While scores obtained indicated differences between participants with SLI and those with typical language development, these results were not felt to be reliable. Many multisyllabic words with complex articulatory sequences are abstract, thus pictures do not elicit an immediate accurate naming response. Furthermore, many of these words require advanced semantic knowledge, which is problematic for participants with SLI, who typically have difficulties with vocabulary acquisition (Clarke & Leonard, 1996; Leonard, 1998; Evans, 2001) and poor naming abilities due to their limited semantic knowledge (McGregor, Newman, Reilly, & Capone, 2002). It is acknowledged that the fact that the Speech Assessment Battery is reliant on repetition is a threat to the validity of the study. However, it is very difficult to elicit complex articulatory sequences from the age group in question using ecologically valid elicitation techniques. The naming/delayed imitation task used in this pre-test was influenced greatly by vocabulary, reading ability, and personality factors. This task was not included in the final battery as differences

noted between the two groups could not be attributed solely to differences in speech production.

6.5.2 Instrumentation

Five types of instruments were used in this study: A Speech Assessment Battery (SAB), an Oral Motor Evaluation (OME), a risk factor questionnaire, a memory assessment battery and a language assessment battery. Each component of the assessment battery is described below, together with information regarding reliability and validity.

Speech Assessment Battery (SAB)

The tasks included in the battery varied with regard to their phonological and motoric complexity, length, familiarity and the effects of long term phonological, morphosyntactic and lexical knowledge (see Chapter 5). The tasks included in the SAB will be discussed below, that is: The Multisyllabic Word List (MWL), Nonsense Word Repetition (NWR), Phrase Repetition (PR), Sentence Repetition (SR), and Tongue Twisters (TT). Examples of each task are provided in Table 6-4, while Appendix G contains lists of all the items and instructions included in the tasks as well as the picture stimuli used for the Tongue Twister task.

Table 6-4: Examples of items included in the Speech Assessment Battery

Task	Examples
Multisyllabic Word List	susceptible consciousness statistics
Nonsense Word Repetition	/pɛ́θətol/ /makəvən/ /mənəmən/
Phrase Repetition	Tom wears shoes Bright blue beam Swiss wristwatch
Sentence Repetition	He likes split pea soup. Shiny seashell necklace. Sheep should sleep in a shed.
Tongue Twisters	Santa's short suit shrunk. Green glass globes glow greenly. Which witches wished wicked wishes.

Multisyllabic Word List (MWL): Catts' (1986) original list contained 52 items of three or more syllables. However, some of these items (such as

Episcopal Church or pistachio) would be unfamiliar to South African children. Such items were removed from the list and only 45 items were presented to the participants, who repeated the words after one presentation.

Nonsense Word Repetition (NWR): The NWR task (Kamhi & Catts, 1986) consisted of a list of 30 nonsense words, each containing three or more syllables. Words were presented once, with no repetition allowed.

Phrase Repetition (PR): These phrases (Catts, 1987 in Lewis & Freebairn, 1992) consist of two to three words, and were thus well within the memory span of participants in this study. With the exception of two words (biscuits and baskets) all the words were monosyllabic. Some of the phrases contain words which have very different sound combinations, for example, "dark blue hat", and are therefore easier to articulate. Other phrases contain very similar sound sequences, for example, "Swiss wristwatch", and are therefore more difficult to produce. Participants repeated the phrases after one presentation by the tester.

Sentence Repetition (SR): The Sentence Repetition task described by Kamhi and Catts (1986) consists of ten short phrases or sentences containing complex phonetic sequences. Each phrase or sentence contained three to six words. Participants repeated the sentences after one presentation by the tester.

Administration of MWL, NWR, PR and SR: All four citation tasks followed the same guidelines. Each item was presented only once. If a participant requested repetition of the stimulus, it was explained that this was not allowed, and the item was scored as NR (No Response). If participants appeared very anxious, the item was repeated, with the explanation that this was not allowed, but the item was still scored as NR.

If the tester made a mistake, which would necessitate repetition, this was not done immediately, as the participant may have been given an unfair advantage. Instead, the tester would indicate that she made a mistake, and continue with the next item on the list. She would return to the omitted item at the end of the test without indicating that she was repeating an earlier stimulus.

Tongue Twisters (TT): Ten tongue twisters were selected for the study. See Appendix D for a description of the development of this task. Each tongue twister

was printed in bold letters below the picture, with each tongue twister on separate A4 sheet of paper. Tongue twisters were graded in length, ranging from three words to six words per item. At least two items of each length were presented.

Administration of Tongue Twisters: In order to compensate for the reading difficulties of the SLI group, the examiner read each tongue twister to the participant and asked the participant to repeat the stimulus. The process was repeated until the participant repeated the tongue twister correctly once. The participant then had to repeat the tongue twister five times, while the picture and written stimulus remained visible to aid recall. These repetitions were timed by the tester using a stopwatch to obtain a total rate for the five repetitions. Repeated reiteration was used, firstly, to differentiate the tongue twister task from the Sentence Repetition task; and secondly, as repeated reiteration has been found to have an error-inducing effect (Wilshire, 1999). A higher error rate would allow the researcher to determine if participants with SLI were more vulnerable in that they produced more errors, and to determine if qualitative differences were apparent between groups.

Scoring of the Speech Assessment Battery (SAB)

Vowel errors were not considered in scoring the tasks. Although all participants spoke English as their home language, the participants represented a number of different cultural groups with subtle dialectal differences which are most apparent in vowel production. It would therefore have been difficult to determine whether vowel differences were the result of speech errors or speech differences.

Each of the speech tasks (Multisyllabic Word List; Nonsense Word Repetition; Phrase Repetition; Sentence Repetition; and Tongue Twisters) was analysed on four levels.

Accuracy Score: A raw score was obtained by adding all the items in which the participant's final response was correct.

Deviation Score: A raw score was derived by adding up all the items in which there was any deviation from the model presented by the tester. Such deviations included any hesitations, repetitions or revisions, or sound errors. See Table 5.2 for a list of all behaviours which were regarded as deviant. A score of 1 was

allocated to any item containing deviations, regardless of how many problem behaviours there were, or whether the final product was accurate.

Number of deviant speech behaviours: Every deviation from the model presented by the tester was recorded and coded using the categories and definitions presented in Appendix J. There could thus be more than one error per deviation. For example, a deviation could consist of a sound substitution, which was corrected using a revision i.e. two separate errors. All the errors for each subtest were added to produce a total raw score per subtest.

Attempt Score: All items which contained more than one attempt to produce the target utterance were tallied to yield a raw score. Any repetition (sound, syllable, word or phrase repetition) or revision was regarded as an additional attempt. The Attempt scores were used in analysing the Tongue Twister time scores, where it was hypothesized that time taken would be affected by the number of attempts participants made to produce a correct response.

A high Accuracy score would reflect good speech performance, while high scores for Deviations, Attempts and Number of Deviant Behaviours would reflect poor speech ability.

Poor Speech Group: The Number of Deviant Behaviours score was hypothesized to be the most sensitive to speech disturbances in this population and was therefore used to identify a Poor Speech group for analysis of risk factors. Risk factors in relation to the general SLI population have been documented in other studies (Tomblin, Smith & Zhang, 1997; Bishop, 2002a), but the current study aimed to analyse risk factors in relation to a specific subgroup of SLI, namely adolescents with poor speech abilities. In order to identify the group of participants who presented with the poorest speech performance, the total Number of Deviant Behaviours across all five subtests of the SAB was compared to the mean of the TD group. All participants whose error score was more than two standard deviations worse than the mean of the TD group were included in a group named the Poor Speech group.

The Tongue Twister task was also analysed in terms of rate. The time taken to repeat each tongue twister five times was recorded, and the total time for all ten items (50 sentences) was added to produce a total rate in seconds for this task.

A sample of 40% (n=25) of the score sheets for the speech tasks were scored independently by a second rater. Ten of these samples were obtained from participants with SLI, while the remaining 15 samples were from typically developing participants.

Oral Motor Evaluation (OME)

Purpose and Description of the OME: Any assessment of speech should include an evaluation of the structural and functional integrity of the speech production system (Kent, 1997). As the study aimed to investigate the speech motor abilities of participants, a sensory examination was not included in the checklist. The speech mechanism was assessed using static examination of speech structures and nonspeech tasks, including simple nonverbal oral movements, repetitions of nonverbal oral movements, and syllabic repetition rates. An OME checklist was compiled based on suggestions by Mason and Simon (1977), Ruscello, St. Louis, Barry and Barr (1982), Robbins and Klee (1987), Crary (1993), Duffy (1995), Kent (1997), Robin, Solomon, Moon and Folkins (1997), Strand and McCauley (1999), and Haynes and Pindzola (2004). This 91-item checklist consisted of 28 items evaluating structural aspects of the face and articulators; 19 items evaluating the function of the speech mechanism during non-speech tasks; and 44 items evaluating the function of the speech mechanism during speech tasks (see Appendix E). Items were categorized according to guidelines provided by Kent (1997).

Structure refers to a structural (static) examination of speech structures. The term "static" refers to postures that can be maintained for a period of time. The static examination gathers information regarding body control and posture, variations of size and general appearance of body structures, and asymmetries of the orofacial complex. The examiner also looks for asymmetry of size or shape, abnormal colour, fasciculations, tremor, tics or other abnormalities. This component of the checklist evaluated the structure of the lips, mandible, maxilla, teeth, palate and velopharynx at rest. Additional aspects in this component included posture, the presence of tremors or tics, and an overall rating of the face to determine if overt dysmorphic features were present.

Function or nonspeech tasks offer the opportunity to observe functional characteristics relevant to speech or other oral motor behaviours (Kent, 1997). In particular, these tasks offer the opportunity to observe isolated muscle systems while performing a specified action free of phonetic restrictions. As Robin, Solomon, Moon and Folkins (1997) pointed out, it is important to distinguish problems of motor control during speech from the linguistic demands placed on the system. Nonspeech tasks also allow for the assessment of individual speech production subsystems, which is not possible during speech tasks (Robin et al, 1997). The function of the lips, mandible, velopharynx and tongue were evaluated on non-speech tasks. Respiration was also rated while the participants were at rest. Both isolated movements (such as protrusion of the tongue) and repetition sequences (such as alternation of lip protrusion and retraction) were included, in order to assess coordination of articulators. Coordination can be defined as "…the synergistic interaction of muscle groups resulting in smooth movement that is performed with the correct range, rate and direction of movement" (Strand & McCauley, 1999, p.84). Poor coordination can be reflected in difficulty with repetitive or rapid alternating movements (Strand & McCauley, 1999), hence such movements were included in both the Function and Speech Function components.

Speech Function refers to simple speech or speech-like tasks. Such tasks included high-effort tasks, such as maximum phonation duration or frication duration, as well as syllable repetition rates. Performance on syllable repetition can be compared to analogous movements on nonspeech tasks (Kent, 1997). The function of the speech mechanism was assessed on isolated phonemes, as well as connected speech. Syllabic repetition rates were assessed. This component included a brief evaluation of the voice, as well as an overall rating of intelligibility and prosody during the narrative discourse sample. One of the hypotheses of this study was that children with SLI would not experience difficulty with simple oral movements, but would break down when several movements have to be integrated. Research in the field of dyslexia has suggested that children with dyslexia have timing problems with motor movements, which are not evident on simple motor tasks, but are observed when several motor

processes have to be integrated (Catts, Gillispie, Leonard, Kail & Miller, 2002). It is thought that a similar principle could apply to speech production in children with SLI, hence diadochokinetic tasks (rapid alternating movements) were included. Assessments of prosody, voice and intelligibility were included in this section (Crary, 1993; Kent, 1997).

Completion of OME: The OME checklist was completed by observing the participants during conversation and throughout the testing session, as well as using a separate evaluation, lasting approximately 5 minutes. The OME involved observation of structures at rest, and by giving simple instructions to elicit oral or speech movements (see Appendix F). Where necessary, the researcher demonstrated what was required. A torch and tongue depressor were used when necessary.

Rating of OME: A rating of 1 was allocated to any particular item if a structural or functional abnormality was noted (see Appendix F). Normative data reported by Kent (1997) were used where relevant to determine ratings. The checklist yielded three ratings: A structural rating, a functional rating, and a speech function rating.

Reliability and Validity of the Speech Assessment Battery (SAB) and Oral Motor Evaluation (OME)

Reliability refers to the reproducibility or dependability of test scores or ratings, as well as the absence of random error variance (Cordes, 1994). Data based on observation of behaviour is only reliable if the observations are not affected by differences among observers or by other variations in the recording context (Cordes, 1994). Reliability of the Speech Assessment Battery was established by using one examiner and standard test instructions for all participants, and utilizing a second rater to observe and rate the administration of the SAB and OME in a subset of the participants. A second rater also transcribed and rated participants' performance on the SAB for a subset of the group.

A measure is regarded as valid if it is accurate and it measures what it purports to measure (Neale & Liebert, 1986; Sarantakos, 1998). The OME checklist is felt to have content validity, that is, it contains content that is directly and representatively sampled from the domain of interest (Neale & Liebert, 1986).

The checklist was based on suggestions obtained from credible literature sources, and reflects consensus among researchers and clinicians regarding the areas to be assessed. In order to confirm content validity, the checklist was also discussed with a speech-language pathologist with extensive experience in assessing speech in paediatric populations, and who lectures in the field at an academic institution. Her suggestions were incorporated in the final checklist.

Criterion validity, or the empirical association of the tasks with some criterion or "gold standard" (DeVellis, 1991), which may lead to predictive validity or concurrent validity, is difficult to establish at this stage of the study. As empirical confirmation of validity is difficult, theoretical or conceptual validation was considered. Sarantakos (1998) suggests that a measure is taken to have theoretical validity if its findings comply with the theoretical principles of the discipline i.e. they do not contradict already established rules of the discipline. The SAB and OME would appear to have theoretical validity, based on the following factors:

Face validity i.e. the tasks seem to measure what it is expected to measure (Sarantakos, 1998). Face validity is judged based on general theoretical standards and on subjective judgment of the researcher. The speech tasks selected for this study thus appear to have face validity, as they meet the requirements described by Kent (1997) for speech assessment. The speech citation tasks, with the exception of the Tongue Twister task, have all been used in previous research studies (Kamhi & Catts, 1986; Lewis & Freebairn, 1992) to assess speech production, and are therefore felt to have content validity as described by Sarantakos (1998). The researcher's subjective judgment, supported by colleagues who are experienced in paediatric speech assessment, is that the instruments have face validity.

Content validity describes whether the measures cover all possible aspects of the research topic (Sarantakos, 1998). In terms of Kent's (1997) description of the components of a good speech assessment, the tasks selected for this study certainly cover all possible aspects of citation tasks. One threat to the validity of the instruments is that all the measures are reliant on repetition. As was discussed above with regard to the pre-test results, it was very difficult to devise tasks involving language formulation, such as naming tasks, which were appropriate for

this age group, and which yielded reliable results. The lack of language formulation tasks is thus acknowledged as a limitation of the current study.

Construct validity refers to a measure's ability to detect differences between two groups known to be different. The MWL and SR can differentiate between reading and language impaired children (Kamhi & Catts, 1986); while some of the tasks have been shown to differentiate between adolescents with a history of phonological disorder and controls (MWL and NWR), and between adults with a history of phonological disorders and controls (MWL, NWR and PR). As will be seen in Chapter 7, the SAB detected differences between the TD and SLI participants, suggesting that it has construct validity.

The Speech Assessment Battery was therefore felt to be both reliable and valid, with some acknowledged limitations.

Risk Factor Questionnaire

Purpose: The risk factor questionnaire (Appendix C) was included to obtain detailed background information about all participants and to identify risk factors that may have contributed to their speech and/or language disorders. The use of questionnaires is based on the questionable assumption that the participants' parents were reliable and keen observers of their children's behaviour (Hegde, 1987). However, in view of the children's ages, and the fact that the TD group would have had limited exposure to professionals who could provide objective records, it was felt that questionnaires were the best option to obtain the required information. The use of questionnaires provided parents the opportunity to consult records, or ask relatives for information where required. However, probing or prompting was not possible, and questions could not be clarified (although some parents contacted the researcher telephonically for clarification). Respondents could also not be motivated to complete all questions, which led to some incomplete questionnaires being returned. Parental report in particular has several disadvantages. Firstly, results are dependent on the informant's recall, which may be faulty. Secondly, in reporting language impairment in family members, underreporting may occur as language impairments may be too subtle to be detected by lay informants. Alternatively, caregivers of language impaired individuals may be sensitized language difficulties, and thus be more aware of

language impairment in other relatives, compared to caregivers of control children, who may not have the same awareness (cf. Spitz, Tallal, Flax & Benasich, 1997). While these disadvantages are acknowledged as weaknesses of the current study, the age of the participants precluded the use of other methods to obtain the relevant information in a cross-sectional study.

Description of Questionnaire: The questionnaire included both fixed-alternative and open-ended questions. Fixed-alternative questions allowed respondents to select an appropriate option. Such questions are easy to administer, code and answer, and allow for comparisons and quantifications, but have limitations in providing all possible answers (Sarantakos, 1998). Open-ended questions were therefore also included, which allowed respondents to offer more details, especially quantifications and justifications (Sarantakos, 1998), and to offer information not foreseen by the researcher.

The questionnaire was developed on the basis of the discussion on risk factors in the previous chapters and addressed the following areas (see Appendix C).

Demographic information for parents: Questions probed maternal and paternal sociodemographic information, including parental age, education, current marital status, and home language.

Pre-, peri- and post-natal history: Information was obtained regarding participants' prenatal and birth history.

Early history: Information regarding developmental milestones and feeding history was obtained as these may be indicative of motor deficits which could co-occur with motor speech deficits.

Medical history: The following areas were probed:

History of otitis media: It is possible that otitis media may contribute to the development of auditory processing deficits (Menyuk, 1992) and that it may impact on language development (Leonard, 1998) and speech production. As was discussed in Chapter 2, Shriberg (2003) postulated that there could be a subgroup of children with phonological disorder that he categorised as Speech Delay – Otitis Media with Effusion (SD-OME), where the phonological disorder is related to a history of otitis media with effusion.

Attention Deficit (Hyperactivity) Disorder (AD[H]D): Attention is required for information processing, hence an attention deficit has implications for resource allocation. Attention also plays a large role in communication development (Haynes, 1994), and AD(H)D may thus have impacted on a child's language development.

Medication prescribed currently or in the past may assist in identifying any attentional or emotional disorders which could have impacted on language learning, or which may impact on test performance.

Significant illnesses or hospitalization, since medical factors could have contributed to a speech and/or language disorder.

Family History of Related Disorders: In view of the familial aggregation of SLI and phonological disorders discussed in earlier chapters, it was important to establish whether children with motor speech deficits in addition to their language impairment also have a significant family history of speech and/or language deficits, that is, whether the co-occurrence of these two disorders has a familial basis. The questionnaire included questions about extended family members in addition to the nuclear family, as extended families provide a greater degree of genetic and environmental variation (Tomblin, Freese & Records, 1992), suggesting that familial aggregation would point to genetic rather than environmental contributions to the disorder. A compromise between a general questionnaire (cf. Lahey & Edwards, 1995) and a listing method (Rice, Haney & Wexler, 1998)[33] was used, whereby the questionnaire asked separate questions about fathers, mothers, siblings and extended family members; and informants had to provide separate information for speech, language and learning difficulties. A listing method is reported to help informants remember the status of family members (Rice et al, 1998).

Educational History: A description of academic difficulties (if any) and a history of grade retention were obtained. For the typically developing participants, this question served as an additional check to ensure they met the

[33] A listing method requires informants to provide a list of names and birthdates of all nuclear and extended relatives, before reporting whether the relative had a history of speech, language, reading, spelling or learning disabilities (Rice, Haney & Wexler, 1998).

selection criteria. For the participants with SLI, this section provided some indication of the participants' academic abilities.

Previous Assessments and Intervention: The detailed questionnaire probed information regarding speech-language and occupational therapy assessments and intervention. For the typically developing participants, this was a further check to ensure they met selection criteria. For participants with SLI, it was important to determine whether they had attended speech-language therapy, and if so, what the presenting diagnosis was and how long intervention lasted. The question regarding occupational therapy aimed to determine if the participants had any previously diagnosed history of motor difficulties.

History of Phonological Disorder: Questions were asked to determine if there was any history of articulation or phonological errors; to obtain a description of the nature and duration of the disorder; and a description of any intervention received for the phonological disorder.

Current Speech Status: Parents/guardians were asked to describe the participants' current speech status, particularly with regard to their ability to produce multisyllabic words. As discussed previously, Shriberg (2003) described a subgroup of children with phonological disorder, who have residual errors which persist into adolescence and adulthood. These residual errors are characterized by common distortions and imprecise speech. Some of the participants with a history of phonological disorder could fall into this subgroup, and it was therefore necessary to determine whether parents/caregivers felt the participants still had some speech difficulties. It was important to find a sensitive descriptor for current speech status. Enrolment in therapy, used in many other studies, would not be appropriate for adolescent participants. In order to ensure that informants understood exactly what was meant by speech impairment, examples of surface symptoms were provided, as was done by Rice, Haney and Wexler (1998).

Completion of Questionnaires: Questionnaires were presented to the parents or guardians of participants in one of three ways:

1) Questionnaires were given to participants on the day of testing and their parents/guardians were asked to return the completed questionnaires to the school

in a sealed envelope for collection by the researcher; or 2) questionnaires were emailed to parents/guardians, and responses were emailed directly to the researcher; or 3) questionnaires were administered telephonically by the researcher. The latter option was only used if questionnaires were not returned as requested.

Memory Assessment Battery

As was discussed in previous sections, memory deficits are characteristic of children with SLI. A hypothesis of this study is that there are interactions among language, memory and speech, and that such interactions may contribute to the limited processing abilities of children with SLI by placing excessive demands on resources during processing tasks. It was therefore essential to evaluate the memory abilities of all participants, particularly aspects of sequential memory and phonological memory which are highly correlated with SLI, to establish the potential impact of these areas on performance on the SAB. Table 6-5 below summarises the tasks used in the memory assessment battery.

Table 6-5: Tasks included in the memory assessment battery.

Task	Purpose
Word Series (CAS) (Naglieri & Das, 1997) Sentence Repetition (CAS) Sentence Questions (CAS)	Preservation or comprehension of a serial organisation of events.
Naming Speed-Pictures (PhAB) (Frederickson, Frith & Reason, 1997)	Phonological retrieval / naming speed.
Children's Test of Nonword Repetition (Gathercole & Baddeley, 1990)	Phonological short term memory.

Rationale for Selection of Memory Tasks: Memory tasks were included which differ with regard to their use of the central executive (Donlan & Masters, 2000). Immediate verbal recall, such as word series, primarily involves the phonological loop. Tasks requiring simultaneous monitoring and storage, such as judgment tasks, also involve the central executive, as well as storage in the phonological loop. Such tasks are judged to be more complex (Donlan & Masters, 2000), although complexity may also be related to aspects of general working memory, such as constrained attention (Cowan, 1998 in Donlan & Masters, 2000). Three

aspects of auditory memory were assessed. These included auditory sequential memory (both short term and working memory), naming speed (phonological retrieval) and phonological short term memory.

Auditory Sequential Memory: Auditory sequential memory was assessed using the Successive Processing subtests of the Cognitive Assessment System (CAS) (Naglieri & Das, 1997). The CAS is based on the PASS model of cognitive processing and assesses the underlying cognitive processes of planning, attention, simultaneous and successive processing in children between the ages of five and 17 years. It was derived from more than 20 years of research and was standardized on 2200 children, while an additional 872 subjects participated in reliability and validity studies. The test has been found to be both reliable and valid (Naglieri & Das, 1997) and the subtests have been researched extensively.

Successive processing has strong sequential components, and is involved in the syntax of language (Naglieri, 1999). The successive processing subtests of the CAS demand the preservation or comprehension of a serial organization of events (Naglieri & Das, 1997). All three successive processing subtests of the CAS were used in this study. These subtests are described below.

Word Series: This subtest consists of nine monosyllabic high-frequency words, which are presented in series ranging from two to nine words. Information is presented in a specific order, and closely resembles other commonly-used tests of short term auditory memory. The tester familiarised the participant with the words to be used in the test and then read the series once, with no repetition of stimuli allowed. The participant had to repeat the word string in the same order.

Sentence Repetition: Nonsensical sentences of increasing syntactic complexity and length were presented once, after two practice items were used to familiarize participants with the task. No repetition of stimuli was allowed. Colour names are used instead of content words, by adding grammatical morphemes where necessary. Complexity of sentences ranged from: *"The white is blue" (*Item 1), to *"The blue reds a green yellow of pinks, that are purple in the brown, and then grays the tan*" (Item 20). An error was defined as "…any inaccuracy, including word substitutions, omissions, additions, reversals, and word ending changes" (Naglieri & Das, 1997, p.77). This task differed from the

Sentence Repetition task used in the SAB in terms of the morphosyntactic complexity and increasing length of stimuli.

Sentence Questions: Sentences similar to those presented in the Sentence Repetition task described above were read to the participants, who had to answer a question about the sentence. For example: *"The blue is yellowing. Who is yellowing?*" (Sample A). The sentence and question could be repeated once at the child's request. This task could also provide an index of working memory, involving the central executive, as the stimulus did not merely have to be repeated, but required processing and comprehension.

Rapid Naming: The Naming Speed – Pictures subtest of the Phonological Assessment Battery (PhAB) (Frederickson, Frith & Reason, 1997) was used to assess retrieval. The PhAB is a standardized test which was designed to assess phonological processing in children aged from 6,0 years to 14,11 years. It was standardized on 629 pupils in the United Kingdom, and the authors report high levels of internal consistency and a low error of measurement. Correlational and factor analysis measurements performed by the authors after the test was standardized, suggest that the subtests are both valid and reliable measures.

It was decided to use picture naming, rather than digit naming, as digit naming is usually done more rapidly than picture naming (Wilson & Cline, 1995), suggesting that digits require less processing time. In view of the age of the participants in the current study, it was preferable to include more challenging tasks, to increase the likelihood of detecting problem areas in this adolescent group. Digit naming may not have been sufficiently sensitive in this population. Letter naming was not used, because of the high incidence of reading difficulties in older children with SLI.

The Naming Speed Test – Pictures consists of a rapid continuous naming task, where the participant has to name a random sequence of line drawings of five common objects as rapidly as possible. The items are presented on a single card in random order, with each object appearing ten times. In accordance with test instructions, the participant was familiarized with the picture stimuli prior to testing. The task consisted of two trials in which the 50 items are presented in a different order.

Underlying processes required for this naming task include perceptual and semantic processes which are required to recognize and identify the stimulus; and phonological processes, which are required to locate the name in long term memory, and process the information to enable the name or label to be articulated (Katz, 1986 in Wilson & Cline, 1995). Kamhi, Catts, Mauer, Apel and Gentry (1988) have suggested that rapid naming may depend on how well the phonological information associated with the relevant items is represented and stored in long-term memory. More recently, it has also been suggested that naming speed can be influenced by a neural timing deficit in poor readers (Catts, Gillispie, Leonard, Kail & Miller, 2002).

*Phonological Short Term Memory***:** Nonword repetition was used to assess phonological short term memory, as this measure is regarded as a "purer" assessment of phonological short term memory capacity than real words (Gathercole & Baddeley, 1990), although, as was discussed in previous chapters, this view may be criticised. During a nonword repetition task an individual invokes phonological processes (such as perception, encoding, retrieval and production) independent of lexical knowledge (Montgomery, 2000b).

Items from the Children's Test of Nonword Repetition (Gathercole, Willis, Baddeley & Emslie, 1994) were used to assess phonological working memory. Gathercole and colleagues report that the phoneme sequences in these nonwords conform to the phonotactic rules of English, and that items were constructed to correspond to the dominant syllable stress patterns in English for words.

Participants were asked to repeat 40 nonwords, 10 each containing two, three, four, and five syllables (Appendix H). Procedures used by Gathercole, Baddeley and colleagues (Gathercole, 1995; Gathercole, Hitch, Service & Martin, 1997) were followed in administering the Children's Test of Nonword Repetition. The participants were told at the beginning of the test that they would hear some "made-up" words. The items were presented in constant randomized sequence for all participants. The next nonword in the sequence was presented after a repetition attempt of the previous item. No repetition of stimuli by the researcher was allowed. An attempt was scored as 0 if the child produced a word differing

from the target nonword by one or more phonemes, and 1 if the repetition was judged to be accurate. A raw score out of 40 was thus derived for this test.

Validity of Memory Tasks with South African Participants

All the above measures were developed in countries other than South Africa, which raises questions regarding the validity of these measures with a South African population. All the participants were first language speakers of English and were not from disadvantaged socioeconomic backgrounds. As a result they were similar to the populations used to standardise or develop the above measures. Furthermore, the subtest from the PhAB has been evaluated with a group of South African children from a similar geographical and socioeconomic background (Cochran, 2003), and was found to have validity with South African children. The Auditory Word Memory subtest of the TAPS (Gardner,1985) which is very similar to the Word Series subtest of the CAS, was found to yield valid norms for South African children who match the linguistic and socioeconomic description of these participants (Mallotas, 2001). The nonword repetition task is reported to lack cultural bias (Campbell, Dollaghan, Needleman & Janosky, 1997; Ellis Weismer et al, 2000). None of the tasks involved complex vocabulary or culture-specific concepts. It was therefore concluded that the memory tasks could be used with participants in this study without concern for linguistic or cultural bias.

Language Assessment Battery

The purpose of the language assessment battery was to provide information regarding the language impaired participants' language abilities, in order to identify correlations among speech, memory and language abilities. This battery was therefore administered only to participants with SLI. In compiling the language battery, the language model proposed by Bloom and Lahey (1978) was used, in that the battery included aspects of language form, content and use[34]. These language areas were assessed in isolation and in discourse tasks. Both receptive and expressive tasks were included. Since the participants in this study

[34] Language is regarded as the interaction of language form, content and use, where language form refers to phonology, morphology and syntax; content refers to semantics; and use refers to pragmatics.

were adolescents, language tasks were included which assess more complex language abilities, such as multiple word meanings, ambiguities and spoonerisms.

Table 6-6 provides a summary of the test battery. Within the language battery there were several standardized measures. While the Phonological Assessment Battery (PhAB) and the Test of Adolescent Language (TOAL-2) have been found to have validity with English-speaking South African children (Mouzouris, 2001; Milburn, 2003), the applicability of the Clinical Evaluation of Language Fundamentals (CELF-R) and the Test of Language Competence (TOLC) have not been established. However, in order to identify correlations with other variables, the standard scores are not of great significance. Patterns of performance, rather than absolute magnitude of scores were considered (Wilson & Risucci, 1986).

Table 6-6: Language assessment battery.

Component Assessed			Test/Procedure	Purposes of test/procedure
FORM	Phonological Awareness		Spoonerisms (PhAB)	Transposition of phonemes in words.
	Syntax	Receptive	Listening Grammar (TOAL-2)	Matching sentences with similar semantic content, despite differing syntactic structure.
		Expressive	Formulated Sentences (CELF-R)	Formulation of simple, compound and complex sentences.
CONTENT	Semantics	Receptive	Listening Vocabulary (TOAL-2)	Understanding of homophones.
			Understanding Ambiguous Sentences (TOLC)	Understanding of ambiguity.
		Expressive	Word Associations	Recall of labels within a semantic class (timed).
USE	Discourse		Narrative Discourse	Assessment of narrative structure.

Each component of the language battery will now be described in more detail.

Phonological Awareness: Phonological awareness[35] forms part of the structure of language, as it requires knowledge of the phonemes used to produce

[35] Phonological awareness is the metalinguistic ability that involves the more or less explicit understanding that words are made of discrete units (Ball, 1993) and is demonstrated in tasks

words, which form part of language. As it has been postulated that phonological awareness difficulties are related to phonological disorder in children, it was important to assess this area. However, it is acknowledged that reciprocal relationships exist between phonological awareness and reading (Blachman, 1994), with phonological awareness being a strong predictor of reading achievement, while phonological awareness abilities are developed through reading (Ball, 1993). In a group of adolescents with SLI, many of whom have reading difficulties, it would therefore be difficult to establish if phonological awareness weaknesses were always part of the disorder, or whether it is the result of limited exposure to reading.

Phonological awareness is demonstrated by a variety of skills (Gilbertson & Bramlett, 1998). Of these skills, phoneme manipulation, including deletion, substitution and reversal are regarded as complex skills (Ball, 1993). A spoonerisms task requiring deletion and substitution would therefore be suitable for the assessment of adolescents.

The Spoonerisms Test, a subtest of the Phonological Assessment Battery (PhAB) (Frederickson, Frith & Reason, 1997) consists of two parts. Each part has to be completed within three minutes. The first part uses semi-spoonerisms, where the first sound of a word is replaced with a new sound; while the second part uses full spoonerisms, where the initial sounds in two words are exchanged (Frederickson, Frith & Reason, 1997).

Receptive Syntax: The Listening Grammar subtest of the Test of Adolescent Language-2 (Hammill, Brown, Larsen & Wiederholdt, 1980) was used to assess receptive syntax. The TOAL is based on a three dimensional model of language incorporating form (spoken vs written language), features (syntax and semantics) and systems (receptive vs expressive language). The Listening Grammar subtest comprises 35 items. Each item comprises of three sentences which are read aloud to the participant, who has to identify the two sentences which have essentially the same meaning. The authors report that the vocabulary of the items is controlled, so that items differ mostly in grammatical features. The authors have addressed issues of reliability in terms of content sampling, time sampling and scorer

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requiring explicit knowledge of the phonological structure of words, such as segmentation and deletion tasks (Marshall, Snowling & Bailey, 2001).

differences; and issues of validity in terms of content validity, criterion-related validity and construct validity. The test appears adequate in terms of reliability and validity.

Expressive Syntax: The Formulated Sentences subtest (CELF-R) (Semel, Wiig & Secord, 1997) assesses the ability to formulate compound and complex sentences. One or two words are read to the participant, who uses these words to generate a sentence about a given picture. Scoring guidelines consider both syntactic and semantic aspects of the sentence. The test includes coordinating and subordinating conjunctions, and correlatives.

*Receptive Semantics***:** The Listening Vocabulary subtest of the TOAL-2 evaluates a child's understanding of homophones in a picture-pointing task. A word is read to the child, who has to identify two pictures which depict possible meanings for that word. The Understanding Ambiguous Sentences subtest of the Test of Language Competence (TOLC) (Wiig & Secord, 1985) requires a child to provide two possible interpretations for a sentence read by the examiner. Scoring reflects the number and accuracy of the interpretations to the stimulus sentences (Wiig & Secord, 1985).

Expressive Semantics: The Word Associations subtest of the Clinical Evaluation of Language Fundamentals (CELF-R) is a verbal fluency task which evaluates the ability to recall items within a semantic class within one minute.

Discourse: Discourse tasks are essential in any speech or language assessment as standardized testing may not provide evidence of the breadth and depth of a child's linguistic skills (Gummersall & Strong, 1999). In order to identify communication disorders, it is important to engage children in discourse that is challenging enough to reveal linguistic vulnerability (Hadley, 1998). As with all the other components of the assessment batteries, the narrative task was included to challenge the processing abilities of the adolescent participants. Narrative discourse requires substantial higher order planning (Hadley, 1998), thus placing more demands on processing resources.

Narrative tasks yield valuable information regarding syntactic production (Gummersall & Strong, 1999), as well as semantic and pragmatic aspects of language. It was particularly the pragmatic aspect of narrative discourse that was

important for the current study. Standardized language tests are not conducive to allowing an individual to display pragmatic competence. It was therefore unrealistic to complete a pragmatic checklist based on participants' pragmatic abilities during the structured assessment. It was felt that the narrative discourse task would allow for some evaluation of pragmatic ability.

The narrative discourse task also allowed for the assessment of speech production in a more linguistically and cognitively challenging task, as it required language formulation, and not just repetition, as in the SAB. Narrative discourse has been found to have high processing demands, which could affect speech production. Speech production on the narrative task was used, in part, to determine the intelligibility rating on the OME.

Narrative discourse was elicited under two conditions, as complexity of narratives produced depends on the elicitation technique (Liles, 1993; Owens, 2004). Two sets of picture sequence cards were presented, each containing a series of 8 pictures from the *Papa Moll Treasure Chest of Picture Stories* (Schubi). The tester sequenced the cards in the correct order. With Set A (Story No. 3), the participant was given time to study the pictures and formulate a story, and the pictures remained visible while he/she related the story. With Set B (Story No. 5), the participant was again given time to study the pictures, but was warned that the pictures would be removed once the participant was ready to tell the story. With both sets of cards, the participants were given the following instructions: "*I want you to look at these cards. They tell a story. I want you tell me the story. Try to make it the best story you can possibly tell. Make it as interesting and exciting as possible*".

The narrative samples were analysed using guidelines provided by Fey (2001) to obtain a narrative quality score. This score is based on ratings awarded for story setting, story characters, plot development, story ending and language sophistication to yield a maximum raw score of 18. A sample of 10% (n=6) narrative samples were analysed and scored by the second rater who assisted with transcriptions.

Validity of Language Tasks with South African Participants.

As with the memory tasks, many of the language tasks were developed in countries other than South Africa, which raises the question of their validity for the population used in this study. The applicability of the TOAL-2 (Mouzouris, 2001) and the PhAB (Milburn, 2003) has been investigated with South African children of a similar background to the participants in this study. In both cases, results obtained by middle class English-speaking monolingual South African children were very similar to the results obtained by the standardization populations. Validity of the CELF-R and the TOLC has not been established in South Africa. Penn (1998) provided an overview of South African research regarding the use of language tests developed elsewhere. She reported that while in some instances the distribution obtained from white English-speaking South African children (who formed the majority of the participants in this study) has been found to be similar to the normative data provided for standardised tests, this is not a general finding. These tests thus have to be interpreted with caution. However, in the 15 years the researcher has worked in a variety of clinical settings in South Africa, and through discussion with a number of colleagues working with a similar population to that used in this study, the consensus among practicing clinicians is that the CELF-R and TOLC produce valid results when used with South African English first-language speakers of a middle class background, that is, children similar to the participants used in this study.

6.5.3 Data Collection Procedures

Test Venue

Participants were tested individually at a time and place convenient to them. In all instances participants were tested in a quiet room with no distractions and limited extraneous noise. Eight participants were tested at their homes, while the rest were tested at their schools.

Testing Time

Participants were either tested during school time or immediately after school, depending on what their schools would allow. Participants who were tested at their homes, were tested in the morning or early afternoon, to avoid the potential effects of fatigue on the test results. For participants with SLI, the

testing session lasted an average of 90 minutes. The time taken depended largely on the participants' speed of responses, and ranged from 75 minutes to 120 minutes. For participants with typical language development the testing session lasted an average of 40 minutes, with a range of 30 minutes to 45 minutes. Most participants completed testing in a single session. Where testing sessions were interrupted by breaks (recess) at school, testing recommenced immediately after the break. Thus some participants had a brief 15-20 minute break in the testing session. Three participants who could not be tested in a single session, owing to school schedules, were tested over two sessions on consecutive days.

Tester

All testing was done by the researcher, a qualified speech-language pathologist with extensive experience in paediatric assessment. Since some of the tasks involved nonwords, it was important to use only one tester, as some studies have shown that accent differences can impact on nonword repetition performance (Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg, 1999). When measures are derived from systematic observation, it is advisable to check for inter-rater agreement (Singleton, Straits & Straits, 1993) by employing two independent raters (Neale & Liebert, 1986). Hence, six of the test sessions (i.e. 10%) were observed by a second speech-language pathologist, also experienced in paediatric assessment, in order to evaluate the reliability of the researcher's ratings, particularly with regard to the Oral Motor Evaluation (OME).

Testing Procedure

Order of Test Administration: It is important to vary the order of test presentation in order to avoid order and sequence effects (Silverman, 1993) which could confound results, hence tests were administered in random order**.** The exception was the memory test battery. Memory tests were always administered first, while attention was still optimal, to avoid the effects of fatigue. However, within the memory test battery, the order of presentation of tests was randomized to some extent, by starting with a different test every session, and varying the sequence of test presentation. The language and speech assessment batteries were

administered next. The order of presentation was varied: Some participants did the whole speech battery before doing the language battery; some did the language battery before the speech battery; and others were given speech and language tests in random order. As with the memory tests, each session started with a different speech or language test, and the order of presentation was varied.

Test Instructions and Administration: Standard test instructions were used. For standardized tests, the instructions and the examples provided in the test manuals were read to the participants. For the speech assessment procedures, the instructions and examples listed on the score sheets were used. All tests were presented using live voice. The fact that validation measures were not used is an acknowledged limitation of the study.

Recording of Sessions: The testing session was recorded digitally. A Newgen digital voice recorder (Model No. TN6403A) with a clip-on microphone was used to ensure good sound quality. On-line transcription, supplemented by notes on the participant's nonverbal behaviours, was also used during the test session to allow for accurate transcription and analysis (James, 1993).

Reports to Participants and Schools

On completion of testing, parents were provided with a brief written report of the test results and were given the opportunity to discuss the results. With parents' consent, results for participants with SLI were also made available to the participants' schools. In the case of participants attending ordinary schools, appropriate referrals were made if further intervention or management seemed indicated. Participating schools were given a written summary of the overall results, and staff members were given the option of attending a workshop where results would be presented.

6.6 Data Analysis

6.6.1 Transcription of Data

Responses to speech, memory and expressive language tasks were digitally recorded, but on-line transcription was also used to consider contextual cues not available on an audio recording, and to ensure that responses were recorded

accurately. All digital files were transcribed, using English orthography for language tasks, and broad phonetic transcription for speech tasks. The nature of the tasks precluded the use of acoustic analysis, as advocated by Shriberg and colleagues (for example, Flipsen, Shriberg, Weismer, Karlsson, & McSweeny, 1999), although it is acknowledged that phonetic transcription has limitations.

Approximately 40% (n=25) of digital files were transcribed by a second rater, the same speech-language pathologist who observed some of the test sessions to check the reliability of the transcriptions.

6.6.2 Risk Factor Questionnaire

Responses to closed-ended and open-ended questions were analysed quantitatively in terms of nominal scales to determine if the following risk factors were present: Significant early history; otitis media/hearing loss; AD(H)D; family history of phonological, language or learning disorders; phonological disorder; and motor deficits. Appendix I describes the categories and criteria that were used for analysis. Questions used to confirm whether the participants met the selection criteria, (parental demographic information, illnesses/ hospitalization, and educational history), were not analysed further.

6.6.3 Scoring of Language and Memory Test Batteries

Standardised tests (CELF-R, TOAL-2, TOLC, PhAB and CAS) were scored and interpreted using the guidelines provided in test manuals. Standard or scaled scores were used for analysis to facilitate comparison across measures, rather than age equivalent scores, which fail to take into account individual differences (McCauley & Demetras, 1990). Raw scores were obtained for the Children's Test of Nonword Repetition.

6.6.4 Inter-Rater Agreement

Inter-rater agreement was calculated using the following formula (Hegde, 1987):

$$\% \text{ Agreement} = \frac{\text{Number of Agreements}}{\text{Number of Agreements} + \text{Number of Disagreements}}$$

The following results were obtained:

OME (n=6): Raters were compared with regard to their allocation of a 1 or 0 score for each item. Inter-rater agreement was 93.41%, with a range of 91.21-97.8%. Disagreements occurred primarily on subtle structural features, such as furrowing of the tongue, or functional aspects which may be subjective, such as posture.

Transcription and Scoring of the Speech Assessment Battery (n=25): Transcriptions were compared per phoneme, with inconsistencies regarding omissions or additions treated as disagreements. Scoring was compared in terms of Accuracy, Deviations and category of error. Inter-rater agreement was calculated for each subtest, as well as for the battery as a whole. Inter-rater agreement for transcription was high, ranging from 97.5% to 99.63%, with a mean of 98.16% for the SAB as a whole. Inter-rater agreement for scoring was also high, ranging from 88.75% to 97.02%, with a mean of 95.07% for the SAB as a whole. Differences in transcription occurred primarily when participants made errors which are difficult to detect on a recording, but which were visible to the tester, such as substitutions of /m/ and /n/, or /f/ and /ɵ/. Differences in scoring occurred most frequently on categories which may be subjective, such as hesitations and prolongations, rather than overt substitution or repetition errors. Listeners tend to accord a low level of attention to hesitation pauses (Field, 2004) and are therefore less likely to detect these.

Narrative Samples (n=6): Transcriptions were compared per word, with omissions or additions of words treated as disagreements. Scoring was compared per category (story setting, story characters, plot development, story ending and language sophistication), where any difference in the rating allocated per narrative quality category was treated as a disagreement. Inter-rater agreement for transcription was high (95.28%). Agreement for scoring of narrative quality was 89%, which is consistent with data reported by Fey (2001).

Inter-rater agreement was found to be high, which implies that the two raters recorded behaviours consistently and similarly, and that ratings were not attributable to variation or inconsistency on the part of the observers. Differences between raters were discussed until consensus was reached.

6.6.5 Statistical Analysis

Comparison of SLI and TD Groups on the Speech Assessment Battery (SAB) and Oral Motor Evaluation (OME)

Descriptive statistics in the form of means, minimum and maximum scores, and standard deviations were calculated for all the measures.

Ratings from the OME and raw scores from the SAB were compared for children with SLI and children with typical language development (TD). On the OME, the Structure and Speech Function scores were not normally distributed. The Tongue Twister Time score was normally distributed. Table 6-7 below indicates which speech measures on the SAB presented with a normal distribution.

The use of parametric statistical procedures was not advisable as only a small number of measures presented with a normal distribution of data, and there was only one case where both variables to be compared were normally distributed. Non-parametric two sample tests were therefore used for comparisons between the SLI and TD group (Mann-Whitney). The exception to this was the Function score on the OME, where results had an extremely narrow distribution. Consequently, this data was treated as categorical information, with scores falling in one of two categories, that is: 0, 1 or 2+. A Chi-Squared analysis was used to compare this variable. Correlational analyses among variables were conducted using Spearman's Correlation Coefficient.

Table 6-7: Distribution of data obtained on the Speech Assessment Battery.

	Accuracy		Deviations		Number of Deviant Behaviours	
	SLI	TD	SLI	TD	SLI	TD
Multisyllabic Word List	√	X	X	X	X	X
Nonsense Word Repetition	√	X	√	√	√	X
Phrase Repetition	X	X	√	X	X	√
Sentence Repetition	X	X	√	X	√	X
Tongue Twisters	X	X	X	X	X	X

Key: *√ = normal distribution; X = not normal distribution.*

Use of SAB to Rule in/Rule out Language Impairment

Likelihood ratio analyses (also known as odds ratios) were used to determine whether the SAB could be used as a diagnostic tool to rule language impairment in or out. A likelihood or odds ratio indicates the likelihood that a given test result would be obtained in an individual with SLI, compared to the likelihood that the same result would be obtained by an individual without SLI. Likelihood (LH) ratios summarise diagnostic accuracy, and according to Deeks and Altman (2004) have several particularly powerful properties that make them more useful clinically than other statistics. Likelihood ratios capture the magnitude of abnormality of test results, thus offering important advantages over sensitivity and specificity (Sonis, 1999). In order to calculate sensitivity and specificity, continuous outcomes (as is the case with the SAB) are dichotomized, with the result that results which are markedly abnormal are lumped with results that are only mildly abnormal. In contrast, likelihood ratios assign a specific value to each level of abnormality. This value can be used to calculate the probability of a disorder for a given level of a test (Sonis, 1999).

Likelihood ratios were calculated as follows:

$$\text{Likelihood Ratio (LR)} = \frac{\text{True positive (or negative) rate}}{\text{False positive (or negative) rate}}$$

Presence or absence of SLI, as determined by the participant selection criteria, was used as the standard. A positive test result (to rule in the presence of SLI) was set as a score on each subtest of the SAB of either 1*SD* or 2*SD* worse than the mean obtained by the TD group. To determine the LH ratio for a positive result, the true positive rate (proportion of participants with SLI with SAB scores either 1*SD* or 2*SD* worse than the mean of TD participants) was divided by the false positive rate (proportion of TD participants with SAB scores 1*SD* or 2*SD* worse than the mean of TD participants). To determine a negative test result (to rule out the presence of SLI), a SAB score within 1*SD* of the mean of the TD group (or better) was set. The false negative rate (proportion of participants with SLI who had SAB scores better than 1*SD* below the mean of the TD group) was divided by the true negative rate (proportion of TD participants with scores better than 1*SD* below the mean of the TD group). LH ratios of greater than 1 indicate

that SAB scores in that range are more likely to come from participants with SLI; while ratios of less than 1 indicate that scores in that interval are more likely to come from TD participants (Deeks & Altman, 2004). The further likelihood ratios are from 1, the stronger the evidence of the presence or absence of SLI, with likelihood ratios above 10 and below 0.1 providing strong evidence to rule in or rule out diagnoses respectively.

Correlations among Language / Memory Measures and the SAB

Raw scores from the OME and the SAB were compared to the raw scores from the Nonword Repetition Task and narrative tasks, as well as the standard scores obtained from the standardized memory and language tests. Spearman Correlation Coefficients were used, as most of the SAB scores were not normally distributed.

The following chapter will describe and discuss the results obtained in this study.

7 Results and Discussion of Results

In accordance with the aims of the study presented in 6.1, results will be presented in four main sections. Firstly, the performance of the specific language impaired (SLI) and typically developing (TD) groups on the Speech Assessment Battery (SAB) will be compared. Secondly, the neuromotor functioning of the two groups will be discussed by comparing oral motor functioning on the Oral Motor Evaluation (OME) as well as participants' history of motor deficits. Thirdly, likelihood or odds ratios indicating the usefulness of the SAB as an index to rule in or rule out language impairment will be discussed. Finally, risk factors associated with poor speech production in adolescents with SLI will be discussed.

7.1 Performance on the Speech Assessment Battery (SAB)

The SLI group presented with significantly poorer scores than the TD group on all aspects of the SAB. While the two groups presented with a similar proportion of types of speech deviations in most categories of deviation, some differences were evident between the two groups.

The results obtained on the SAB will be presented in two sections. Firstly the scores obtained on the SAB (Accuracy, Deviations, Number of Deviant Behaviours and Tongue Twister time) will be compared for the adolescents with specific language impairment (SLI) and typical language development (TD). In this section, correlations among the participants' SAB scores and their language and memory abilities will also be presented. Thereafter the types of speech deviations that occurred will be categorized and described.

7.1.1 Comparison of SAB Scores

Scores obtained on the five components of the SAB, namely Multisyllabic Word List (MWL), Nonsense Word Repetition (NWR), Phrase Repetition (PR), Sentence Repetition (SR) and Tongue Twister (TT) tasks, were compared across TD and SLI participants in terms of Accuracy[36], Deviation[37] and Number of

[36] Accuracy raw scores for each test were obtained by adding all the items in which the participant's final response was correct. A high score reflects good speech production.

[37] Deviation raw scores were calculated by adding all the items in which there was any deviation from the model presented by the tester, regardless of the accuracy of the final response. A low

Deviant Behaviours scores[38]. The Accuracy score indicated whether the final production of each item was correct. The Deviation score was included in the analysis to determine if participants with SLI required more effort to produce responses, even if the final response was correct. The Number of Deviant Behaviours score provided further evidence for the amount of effort required to produce correct speech output. For example, a participant who produced five deviant speech behaviours within one deviant item, clearly had poorer speech production than a participant with only one deviant speech behaviour in an item.

The SLI and TD groups presented with highly significant differences for all scores on all tasks, as can be seen in Table 7-1 which presents the results of the statistical analysis.

Table 7-1: Results of Wilcoxon Scores (Rank Sums) two-sample test for Accuracy, Deviation and Number of Deviation Behaviours scores for the SAB.

	MWL	NWR	PR	SR	TT
Accuracy	$\alpha < 0.0001$	$\alpha < 0.0001$	$\alpha < 0.0001$	$\alpha = 0.0014$	$\alpha = 0.0015$
Deviation	$\alpha < 0.0001$	$\alpha < 0.0001$	$\alpha < 0.0001$	$\alpha = 0.0026$	$\alpha < 0.0001$
Number of Deviant Behaviours	$\alpha < 0.0001$	$\alpha < 0.0001$	$\alpha = 0.0001$	$\alpha = 0.0019$	$\alpha < 0.0001$

Key:
MWL = Multisyllabic Word List
NWR = Nonsense Word Repetition
PR = Phrase Repetition
SR = Sentence Repetition
TT = Tongue Twisters

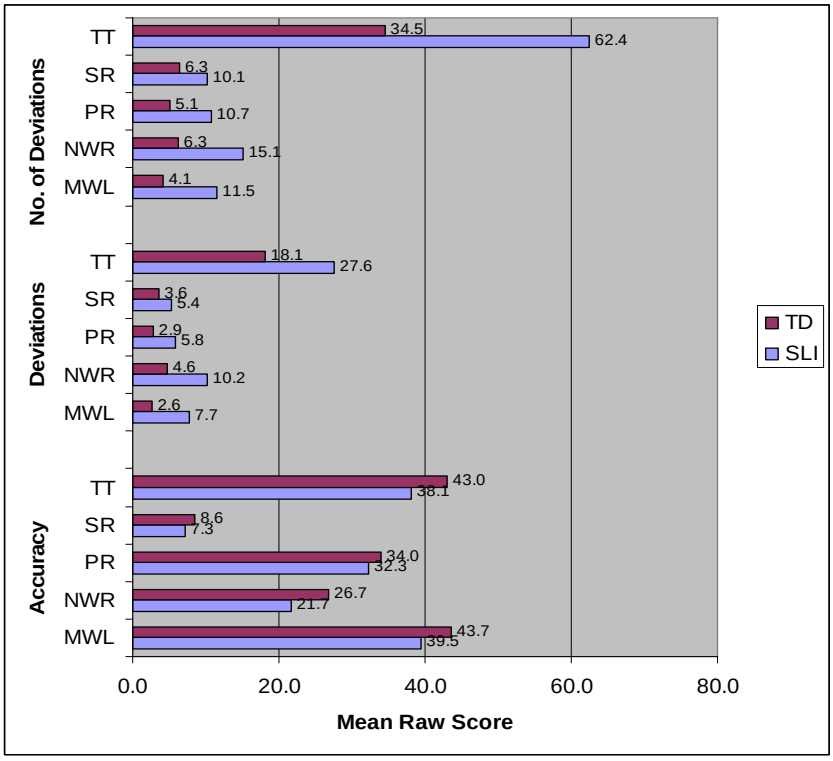
The SLI group obtained poorer Accuracy scores and presented with higher Deviation scores, as well as a greater Number of Deviant Behaviours across all five tasks on the SAB (see Figure 7-1 for a comparison of mean scores).

The SLI group had poorer minimum and maximum scores than the TD group for all tasks (see Table 7-2). While many TD participants obtained the maximum possible Accuracy score for the various tasks, several TD participants presented with errors on the speech tasks, particularly the Tongue Twister task.

score reflects good speech production. Such deviations could include hesitations, repetitions or revisions, or sound errors. Appendix J lists deviant behaviours.

[38] The Number of Deviant Behaviours score was derived by coding every deviation from the stimulus presented by the tester, using the categories and definitions presented in Appendix J. All the deviant behaviours for each subtest were added to produce a total raw score per subtest. High scores indicate poor speech production.

These errors by TD participants suggest, firstly, that the tasks were taxing to the speech production system of even typically developing adolescents; and secondly, that neuromotor coordination of the articulators is still developing in this age group. This finding is not unexpected, in view of the fact that the neurological control of the speech system is not fully mature in early adolescence (Walsh & Smith, 2002).



Key:
MWL = Multisyllabic Word List
NWR = Nonsense Word Repetition
PR = Phrase Repetition
SR = Sentence Repetition
TT = Tongue Twisters

Figure 7-1: Comparison of mean Accuracy, Deviation and Number of Deviant Behaviours scores for the Speech Assessment Battery (SAB).

The SLI group managed to obtain similar *maximum* Accuracy scores to TD participants (with the exception of Nonsense Word Repetition), which suggest that at least some SLI participants performed similarly to TD participants on these tasks (see Table 7-2). However, *minimum* Accuracy scores for SLI participants were much poorer than those obtained by TD participants. While several TD participants presented with no Deviations for many of the tasks, all SLI

participants had at least two deviant items per task. From Table 7-2 it is evident that the SLI group obtained much poorer maximum Deviation and Number of Deviant Behaviours scores than the TD group for all tasks.

The SLI group presented with a much larger range of performance across tasks, as is reflected in the larger *standard deviations* for all scores. This large range of scores is reflective of the heterogeneity of the SLI population, and points to the possibility of subgroups of SLI participants, differentiated by their performance on speech tasks.

Table 7-2: Ranges and standard deviations for Accuracy, Deviations and Number of Deviant Behaviours scores for the SAB.

Task		Accuracy		Deviations		Number of Deviant Behaviours	
		SLI	TD	SLI	TD	SLI	TD
MWL (45 items)	**Range**	29-45	41-45	2-18	0-8	2-25	0-15
	(*SD*)	(3.69)	(1.30)	(3.95)	(2.36)	(6.67)	(4.21)
NWR (30 items)	**Range**	14-28	21-30	4-18	0-11	4-30	0-22
	(*SD*)	(4.21)	(2.71)	(4.18)	(3.06)	(6.82)	(4.75)
PR (35 items)	**Range**	30-35	32-35	2-9	0-8	2-30	0-12
	(*SD*)	(1.40)	(0.93)	(1.85)	(1.71)	(5.99)	(3.28)
SR (10 items)	**Range**	1-10	6-10	2-10	1-7	2-19	2-17
	(*SD*)	(1.73)	(1.20)	(2.17)	(1.84)	(4.81)	(4.28)
TT (50 items)	**Range**	19-50	23-50	8-36	12-37	16-85	19-67
	(*SD*)	(6.90)	(6.32)	(6.46)	(5.30)	(16.65)	(11.42)

Key:
MWL = Multisyllabic Word List
NWR = Nonsense Word Repetition
PR = Phrase Repetition
SR = Sentence Repetition
TT = Tongue Twisters

Despite the significant overall group differences between the TD and SLI group, there was overlap of individual scores (see scattergrams in Appendix K) with some TD participants obtaining similar scores to participants with SLI and vice versa. While there is substantial overlap of Accuracy scores, there is less overlap of Deviation scores, and even less for Number of Deviant Behaviours.

Accuracy Scores

Accuracy scores indicated that participants with SLI were more likely to produce inaccurate final attempts than TD participants, who found this test battery relatively easy. It is important to note that the SLI group's Accuracy scores were poor across all speech tasks as, with the exception of the Tongue Twister task,

means obtained by the SLI group were at least 1*SD* below those of the TD group. One can therefore not argue that lexical or syntactic knowledge alone may have impacted on results, because, as was discussed in Chapter 5, tasks differed with regard to syntactic and lexical complexity.

Auditory memory abilities also did not appear to influence results substantially, as participants with SLI struggled with Phrase Repetition items despite the fact that they all had a memory span of more than three words (as tested on the Word Series subtest of the CAS), and differences were noted on tasks that were primarily reliant on phonological short term memory (NWR), as well as tasks that relied on both short term and long term verbal memory (MWL, PR, SR and TT) and tasks where visual cues were provided (TT). While auditory memory abilities were no doubt tapped by the nature of the tasks (repetition), poor auditory memory or linguistic knowledge alone cannot explain the differences between groups on all five tasks.

Although results on the Phrase and Sentence Repetition tasks were statistically different for the two groups, the mean raw scores differed by less than two points. On both tasks, standard deviations were very small, with the result that a participant's performance on one item could determine whether they fell more than one standard deviation from the mean. Thus, while the results for these two tests have statistical significance, they may not yield results that are clinically significant in terms of distinguishing SLI from TD participants.

Deviation Scores

With the exception of the Sentence Repetition task, all the mean Deviation scores obtained by the SLI group were at least 1*SD* worse than that of the TD group. The challenging nature of the Tongue Twister task is reflected in the high Number of Deviant Behaviours obtained by both groups.

In Appendix L, the mean Deviation scores obtained by TD participants are compared to results obtained by unimpaired late adolescents and adults on the SAB (Alston, 2005; Karodia, 2005; Philippou, 2005; Signer, 2005). Developmental changes can be seen in terms of improved mean scores for the different subtests, suggesting that performance on these tasks will improve with age, as neuromotor coordination has a protracted development (Kent, 1999).

One of the crucial questions in this study was not merely whether SLI participants could produce complex speech stimuli, but how much effort was required for them to produce these stimuli accurately. When comparing Accuracy and Deviation scores, it is apparent that across all tasks there were more deviant items than inaccurate scores, and that SLI participants produced more deviations for each accurate item than the TD group. Participants thus managed to produce accurate responses (Accuracy score) despite experiencing difficulties on the items (Deviations). When deviant speech behaviours occurred, TD participants were more successful than participants with SLI in producing a correct final response.

Number of Deviant Behaviours

With the exception of the Sentence Repetition task, more than two thirds of the SLI group (71-84%) scored more than 1*SD* below the mean of the TD group (compared to 10-22% of TD participants), and at least one third scored more than 2*SD* below the mean of the TD group. Apart from two participants all the participants with SLI scored more than 1*SD* below the mean of the TD group on at least two subtests of the SAB. On average, they scored below 1*SD* from the TD mean on 3.4 subtests.

As was expected, the Tongue Twister task was found to be the most difficult by both groups, although it should be noted that there was more opportunity for errors to occur on this task. The Tongue Twister task consisted of ten sentences repeated five times each (230 words in total), thus yielding more words on which errors could occur, than, for example, the Multisyllabic Word List (45 words) or Nonsense Word Repetition (30 words).

When comparing the results obtained by TD participants with that of typical older people (an 18-year old group and a young adult group with a mean age of 24 years) (see Appendix L), it is apparent that performance on the SAB, as measured by Number of Deviant Behaviours, is related to development. The mean Number of Deviant Behaviours obtained by these 13-year old TD participants is substantially poorer than the scores obtained by either an 18-year old group or a young adult group (Alston, 2005; Karodia, 2005; Philippou, 2005; Signer, 2005).

In comparing the Number of Deviant Behaviours to the Deviation scores, it is apparent that, on average, each deviant item included more than one deviant behaviour. It is interesting to note that the proportion of Deviations to Number of Deviant Behaviours is consistent for the SLI and TD groups for the Multisyllabic Word List (SLI=0.66; TD=0.65) and the Phrase Repetition Task (SLI=0.54; TD=0.56). Differences become apparent when comparing the proportion of deviations to Number of Deviant Behaviours on Sentence Repetition (SLI=0.53; TD=0.57), and even more so on the Nonsense Word Repetition Task (SLI=0.68; TD=0.74) and the Tongue Twisters (SLI=0.44; TD=0.52). SLI participants appear to make proportionally more errors than TD participants on Nonsense Words and Tongue Twisters, suggesting that SLI participants find these two tasks particularly difficult. These two tests were hypothesized to be the most difficult because of the absence of syntactic and semantic support and articulatory complexity in the Nonsense Word Repetition task, and the sustained coordination of complex movements by the articulators for the Tongue Twister task.

Time Taken: Tongue Twisters

The time taken to complete all 10 items of the Tongue Twister task was compared for SLI and TD participants. The SLI group took longer than the TD group to perform every item on the test, and a t-test for equal variance confirmed that this difference is statistically significant (t=0.0007). Results for individual items are presented in Figure M1 in Appendix M. During testing, items 6, 7, and 8 were subjectively perceived to be the most difficult items because of their motoric complexity, particularly for SLI participants. This perception is confirmed by the fact that these three items took the longest for all participants (with the exception of TD performance on item 6). Thus, although these items were shorter than items 9 and 10, participants took longer to complete the five repetitions.

The overall mean time taken by SLI participants was 146.68 seconds (*SD* 22.79; range 103.65s-203.62s), while the mean time for TD participants was 127.13 seconds (*SD* 20.19; range 94.50s-172.95s). Thus, overall the SLI group performed the Tongue Twister task much more slowly than TD participants. Only one SLI participant obtained a score below 110 seconds, while 19% of TD

participants completed the task in less than 110 seconds. In terms of slower scores, 16% of TD participants and 42% of SLI participants completed the task in more than 150 seconds. Figure 7-2, clearly illustrates the distribution of scores in the two groups.

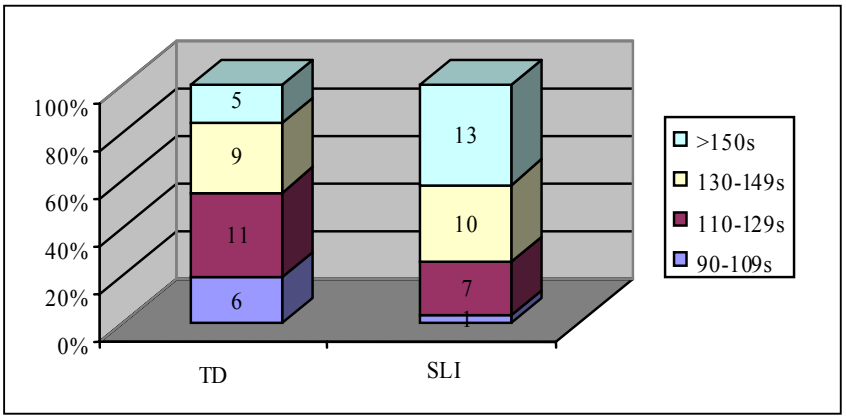


Figure 7-2: Distribution of participants: Comparison of SLI and TD time taken (seconds) for Tongue Twisters.

The longer time taken by SLI participants to complete the Tongue Twister task is not necessarily indicative of a slower rate of articulation. Flipsen (2002), for example, reported that even adolescents with a history of speech delay had a speech rate (as measured in syllables per second) comparable to typically developing peers. Instead, it is postulated that the SLI participants made more errors on this task (as was discussed above), which may have resulted in more attempts to self-correct; and that a higher number of revisions, hesitations and repetitions would have increased the time taken to complete this task. This hypothesis was confirmed using Spearman's correlation coefficient to determine correlations between time taken on the Tongue Twisters and all other measures on all five speech tests as well as the OME (see Table M1 in Appendix M). In this comparison, Attempt scores were included, that is the number of repetitions and revisions used by participants.

For SLI participants there was a strong correlation between number of attempts (repetitions and revisions) on the Tongue Twister (TT) task (0.61, $p<0.001$), as well as a moderate correlation with the Number of Deviant

Behaviours (0.50, $p<0.01$) and Deviation scores (0.48, $p<0.01$) of the TT task. These correlations between time taken and the Deviations, Number of Deviant Behaviours and repetitions/revisions provide support for the hypothesis that the slower performance recorded on the TT task by SLI participants was due to their higher rate of deviant speech behaviours, rather than a slower speech rate.

In contrast, for TD participants there were no significant correlations between time taken and any of the other measures on the Tongue Twister task. There were moderate correlations with Accuracy on the MWL (0.37, $p<0.05$), Deviations on MWL (0.40, $p<0.05$), NWR (0.36, $p<0.05$), and SR (0.42, $p<0.05$), Number of Deviant Behaviours scores on SR (0.43, $p<0.05$), as well as a stronger correlation with the Structure score of the OME (0.53, $p<0.01$). Structural defects may thus have impacted to some extent on the time taken on Tongue Twisters for TD participants, while the number of problematic items on single word tasks and sentences also correlate with time taken.

The results obtained on the Tongue Twister task reflect a similar pattern to results obtained by Hill et al (1997, in Hill, 2001) on a finger opposition task. In that study, participants with SLI differed markedly from age-matched controls in terms of number of sequences completed in twenty seconds, and in the number of errors made.

Correlations among SAB Scores and Language and Memory Tasks

Significant correlations were found between expressive syntax and Accuracy, Deviation and Number of Deviation scores on all tasks of the SAB. The single word tasks correlated with short term memory measures, particularly phonological short term memory, while the Multisyllabic Word List also correlated with vocabulary measures. Table 7-3 reflects the results of the correlation analysis using Spearman's Correlation Coefficient correlations for the SAB scores, OME ratings and language tasks, while Table 7-4 reflects correlations with memory tasks. Language results for individual participants with SLI are presented and discussed in Appendix N, and results for memory tasks for all participants are presented in Appendix O.

Table 7-3: Correlations between Speech Assessment Battery scores and language test scores for SLI participants.

		Narrative	TOAL-2 LV	TOAL-2 LG	TLC Ambig	CELF-R FS	CELF-R WA	PhAB Spoonerisms
OME	Structure	-0.029 p=0.878	-0.006 p=0.973	-0.041 p=0.826	-0.128 p=0.492	-0.126 p=0.499	0.259 p=0.160	-0.014 p=0.940
	Function	-0.411 p=0.022	-0.194 p=0.296	0.118 p=0.526	0.084 p=0.653	-0.053 p=0.775	-0.016 p=0.932	0.086 p=0.647
	Speech Function	0.122 p=0.514	0.174 p=0.349	-0.102 p=0.585	-0.309 p=0.091	-0.327 p=0.073	-0.037 p=0.845	-0.470 p=0.008
Accuracy	MWL	-0.191 p=0.303	0.348 p=0.055	0.167 p=0.369	0.317 p=0.082	0.548 p=0.001	0.049 p=0.794	0.064 p=0.732
	NWR	-0.510 p=0.003	0.003 p=0.986	-0.101 p=0.589	0.150 p=0.419	0.408 p=0.023	-0.203 p=0.272	0.065 p=0.727
	PR	0.274 p=0.136	0.412 p=0.021	0.039 p=0.837	0.412 p=0.021	0.457 p=0.010	0.417 p=0.019	0.015 p=0.935
	SR	-0.084 p=0.653	0.093 p=0.619	0.213 p=0.251	0.214 p=0.247	0.663 p=0.000	0.259 p=0.159	0.238 p=0.197
	TT	0.092 p=0.623	0.115 p=0.536	-0.096 p=0.607	0.177 p=0.341	0.098 p=0.600	0.008 p=0.967	0.363 p=0.045
Deviations	MWL	0.055 p=0.768	-0.361 p=0.046	-0.138 p=0.460	-0.235 p=0.202	-0.505 p=0.004	-0.065 p=0.727	-0.143 p=0.443
	NWR	0.299 p=0.102	-0.173 p=0.351	0.102 p=0.586	-0.228 p=0.217	-0.435 p=0.015	0.130 p=0.484	-0.104 p=0.579
	PR	0.005 p=0.978	-0.292 p=0.111	0.017 p=0.926	-0.261 p=0.157	-0.418 p=0.019	0.065 p=0.728	0.024 p=0.896
	SR	-0.021 p=0.912	-0.157 p=0.400	-0.435 p=0.014	-0.248 p=0.179	-0.554 p=0.001	-0.332 p=0.068	-0.244 p=0.187
	TT	-0.195 p=0.292	-0.348 p=0.055	-0.072 p=0.702	-0.348 p=0.055	-0.428 p=0.016	-0.159 p=0.392	-0.248 p=0.178
Number of Deviant Behaviours	MWL	0.039 p=0.834	-0.383 p=0.033	0.028 p=0.881	-0.097 p=0.604	-0.403 p=0.024	0.067 p=0.720	-0.016 p=0.934
	NWR	0.340 p=0.061	0.035 p=0.850	0.086 p=0.644	-0.031 p=0.866	-0.361 p=0.046	0.164 p=0.379	-0.008 p=0.965
	PR	-0.035 p=0.852	-0.256 p=0.165	0.091 p=0.626	-0.235 p=0.204	-0.463 p=0.009	-0.023 p=0.904	-0.035 p=0.850
	SR	-0.095 p=0.610	-0.158 p=0.397	-0.234 p=0.206	-0.237 p=0.200	-0.497 p=0.004	-0.285 p=0.120	-0.098 p=0.598
	TT	-0.240 p=0.194	-0.380 p=0.035	-0.173 p=0.351	-0.386 p=0.032	-0.325 p=0.075	-0.156 p=0.402	-0.378 p=0.036

p<0.05
p<0.01
p<0.001

Key: *MWL=Multisyllabic Word List*, *NWR=Nonsense Word Repetition*, *PR=Phrase Repetition*, *SR=Sentence Repetition*, *TT=Tongue Twisters*, *LV=Listening Vocabulary*, *LG=Listening Grammar*, *Ambig=Ambiguities*, *FS=Formulated Sentences*, *WA=Word Associations*

Language Abilities and Correlations with the SAB and OME for the SLI Group

Discourse did not correlate significantly with SAB and OME measures, although an unexpected correlation was found between narrative quality and the OME Function rating. Reasons for this correlation are not immediately clear, and require further investigation. Children with SLI are known to have impaired

narrative discourse abilities, and from the current study it is apparent that children with SLI also have impaired Function ratings on the OME. The correlation may thus be the result of the fact that these two deficits are both characteristic of SLI, and thus co-occur. Both OME Function and narrative discourse reflect high task demands, albeit in two entirely different domains (motor coordination vs language). The deficits in these two areas may thus reflect underlying processing difficulties.

Semantic abilities did not correlate with any of the SAB or OME measures, with the exception of the vocabulary task and the Multisyllabic Word List (MWL). This finding supports the hypothesis that performance on the MWL may be mediated by vocabulary knowledge. Nonetheless, the correlation between vocabulary and the MWL scores is not strong, and scores were poor on all SAB tasks, suggesting that impaired vocabulary knowledge is not the primary reason for breakdown on this speech task.

Receptive syntax did not correlate significantly with the speech tasks, with the exception of the Deviation score on the Sentence Repetition task, and is therefore not thought to interact in a noteworthy manner with the speech tasks.

Expressive syntax, on the other hand, was frequently correlated with SAB measures. It correlates most strongly with SR measures, but also correlates with PR, MWL and NWR measures. While the correlation with PR and SR tasks supports the hypothesis that expressive syntax abilities influence performance on tasks involving phrases and sentences, the correlation with single word tasks is somewhat unexpected. These correlations between expressive syntax and speech production can be explained in a number of ways. Firstly, impaired morphosyntax (particularly expressive syntax) is regarded as one of the key defining features of SLI. From the results presented above, it appears as if impaired speech production, as measured on the SAB is also a characteristic feature of children with persistent SLI. Impairments in these two areas may therefore co-occur. Edwards and Lahey (1998) proposed that the high correlation between inaccuracies on their nonword repetition task and expressive language measures could be explained by the common underlying processes involved in producing spoken language. The same explanation could hold for

results in the current study. Secondly, the Formulated Sentences test used to assess expressive syntax is regarded as a very demanding task, as the task is both complex, and constrained in its response requirements (Gupta, MacWhinney, Feldman & Sacco, 2003), which can therefore reveal underlying processing deficits. It is possible that the tasks on the SAB are similarly demanding, and that both expressive syntax and speech production reflect a limited processing capacity. Thirdly, speech production abilities may impact on expressive syntax: Poor speech production may make it more difficult to produce complex sentences, thus increasing the complexity of expressive syntax tasks, and placing more demands on a limited processing capacity. This view is similar to that expressed by Edwards and Lahey (1998, p.305): "The overload placed on some children because of difficulties with phonological processing could influence their production of morphology and syntax". The high correlation of speech deficits and expressive syntax is similar to findings by Shriberg and Austin (1998), that speech disorders are associated two to three times more frequently with expressive disorders than receptive disorders, and that there is greater comorbidity of speech disorders with syntactic deficits than vocabulary deficits.

Phonological awareness (Spoonerisms) correlated with measures reflecting high demands on phonological output, namely the Speech Function, TT Accuracy and TT Number of Deviant Behaviours scores. This finding provides some support for the hypothesis that speech production may constrain performance on complex linguistic tasks. It could be argued that phonological processing (as measured on the Spoonerisms task) could influence performance on a tongue twister task. However, such an argument does not explain why poor phonological processing impacted on a task involving redundant sentences, where both syntactic and lexical knowledge could aid performance, but not on single word tasks which are much more reliant on phonological processing in the absence of syntactic and semantic redundancy. In view of the fact that Spoonerisms also correlated with Speech Function ratings, it seems probable that it is more likely that speech production is impacting on participants' performance on the Spoonerisms task, than vice versa. The Spoonerisms task is highly complex, placing heavy demands on verbal working memory. Many participants

were seen to verbalise their attempts before providing final responses. Poor articulation can impact on this task, firstly in terms of inducing errors which require correction; and secondly, in slowing response time on this timed task.

Previous studies regarding the presence of concurrent language deficits in children with residual errors have yielded inconclusive or mixed results (Flipsen 2002), which led Flipsen to hypothesize that language deficits may need to be specific to a particular domain of language in order to have an impact on speech-sound normalization. Results from the current study suggest that there is a high co-occurrence of expressive syntax deficits and residual speech errors, although there is insufficient information to speculate about the direction of the relationship. The correlation may reflect common output constraints, possibly linked to processing limitations.

Auditory Memory and Correlations with the SAB and OME for TD and SLI Groups

As was anticipated, SLI participants obtained worse scores than TD participants on all memory tasks, and had a much wider range of performance than TD participants. Nonetheless, the mean scores obtained by the SLI group were within one standard deviation of the test mean on all standardized tests. Thus these SLI participants did not present with marked memory deficits as measured by these tasks.

The SLI group obtained a markedly lower mean score on the Children's Test of Nonword Repetition (CNRep) than the TD group. A Wilcoxon Rank Sums procedure confirmed that these results are significantly different ($p<0.0001$). This finding is in line with reports in the literature that nonword repetition is one of the characteristic deficits of children with SLI and that mean scores for SLI and TD groups are different on this task (Montgomery, 1995; Bishop, North & Donlan, 1995; Edwards & Lahey, 1998). Results of the present study extend findings reported by Montgomery (1995) that nonword repetition is still impaired in older children, although his sample was only aged 9 to 11 years. The current study indicates that at age 13 to 14 years, SLI participants (as a group) still have markedly poorer nonword repetition scores than age-matched peers. Bishop et al (1995) found that the Children's Test of Nonword Repetition

is a highly sensitive indicator of SLI, capable of identifying individuals with a history of SLI, even if their current scores on language tests are within the average range. Bishop et al's findings are relevant for the current study, where many of the participants with SLI presented with relatively mild impairments as measured by standardised tests, yet still presented with deficits of nonword repetition.

OME ratings had few notable correlations with memory tasks, particularly with regard to Structure and Function ratings. Speech Function ratings for TD participants correlated with the CAS Sentence Repetition task. As it is unlikely that auditory memory impacts on performance on the OME, it is possible that poor speech function abilities may have influenced performance on this auditory memory task.

Short term memory tasks for **unrelated material** (Word Series) correlated with all speech tasks except Phrase Repetition in the TD group, while in the SLI group short term memory tasks correlated only with the Nonsense Word Repetition task of the SAB.

Short term memory tasks for **related material** (Sentence Repetition) correlated primarily with single word tasks for the SLI group. This finding is unusual, as one expects strong correlations with the SAB Sentence Repetition speech task, as was found in the TD group. It appears that for the SLI group, the two Sentence Repetition tasks tap different abilities. The difference may lie in the construction of the sentences. In the CAS task, the words are predictable and motorically easy to produce. The SAB Sentence Repetition task, on the other hand, has less predictable words and the motoric sequences within these words are also designed to be difficult. The poor scores obtained by the SLI group on the SR test of the SAB, may thus truly reflect difficulties with speech production rather than sentence memory.

As was expected, **phonological short term memory** (Children's Test of Nonword Repetition) correlated most highly with performance on single word SAB tasks, i.e. multisyllabic and nonsense words. These results may suggest that, for the TD group, phonological memory is correlated with performance on single word repetition tasks, whether the words to be repeated are real or not.

Table 7-4: Correlations between memory scores and scores obtained on the OME and SAB.

	Word Series (CAS)		Sentence Repetition (CAS)		Sentence Questions (CAS)		Picture Naming (PhAB)		Nonword Repetition	
	SLI	**TD**	**SLI**	**TD**	**SLI**	**TD**	**SLI**	**TD**	**SLI**	**TD**
Structure	-0.133 p=0.476	-0.027 p=0.884	-0.179 p=0.336	-0.185 p=0.320	-0.412 p=0.021	-0.108 p=0.562	-0.095 p=0.610	-0.419 p=0.019	-0.270 p=0.142	-0.297 p=0.105
Function	0.095 p=0.611	0.247 p=0.180	0.149 p=0.424	0.112 p=0.549	-0.101 p=0.589	0.101 p=0.589	-0.347 p=0.056	0.006 p=0.973	-0.082 p=0.662	-0.104 p=0.577
Speech Function	0.016 p=0.931	-0.315 p=0.085	-0.091 p=0.625	-0.535 p=0.002	-0.181 p=0.330	-0.399 p=0.026	0.007 p=0.968	-0.161 p=0.387	0.012 p=0.947	-0.145 p=0.436
MWL: Accuracy	0.209 p=0.792	0.487 p=0.005	0.465 p=0.008	0.435 p=0.015	0.275 p=0.134	0.493 p=0.005	-0.035 p=0.850	0.217 p=0.241	0.572 p=0.001	0.652 p<0.001
MWL: Deviation	-0.136 p=0.465	-0.445 p=0.012	-0.417 p=0.020	-0.380 p=0.035	-0.236 p=0.201	-0.547 p=0.001	0.091 p=0.625	-0.248 p=0.179	-0.492 p=0.005	-0.495 p=0.005
MWL: NDB	-0.097 p=0.603	-0.482 p=0.006	-0.371 p=0.040	-0.355 p=0.050	-0.238 p=0.197	-0.527 p=0.002	0.131 p=0.482	-0.223 p=0.228	-0.591 p<0.001	-0.471 p=0.008
NWR: Accuracy	0.466 p=0.008	0.442 p=0.013	0.551 p=0.001	0.360 p=0.047	0.420 p=0.019	0.314 p=0.085	-0.121 p=0.517	0.269 p=0.143	0.445 p=0.012	0.569 p=0.001
NWR: Deviation	-0.430 p=0.016	-0.464 p=0.009	-0.568 p=0.001	-0.429 p=0.016	-0.402 p=0.025	-0.327 p=0.073	0.223 p=0.227	-0.370 p=0.041	-0.417 p=0.019	-0.594 p<0.001
NWR: NDB	-0.328 p=0.072	-0.418 p=0.019	-0.404 p=0.024	-0.341 p=0.061	-0.402 p=0.025	-0.266 p=0.147	0.186 p=0.317	-0.301 p=0.099	-0.342 p=0.060	-0.463 p=0.009
PR: Accuracy	0.031 p=0.838	0.347 p=0.055	0.0269 p=0.143	0.153 p=0.410	0.147 p=0.430	-0.010 p=0.957	0.094 p=0.615	-0.332 p=0.068	0.029 p=0.878	0.322 p=0.078
PR: Deviation	-0.260 p=0.158	-0.215 p=0.245	-0.341 p=0.060	-0.259 0.160	-0.188 p=0.312	-0.296 p=0.106	0.103 p=0.583	-0.073 p=0.696	0.044 p=0.812	-0.216 p=0.243
PR: NDB	-0.183 p=0.325	-0.013 p=0.945	-0.144 p=0.439	-0.022 0.908	-0.194 p=0.296	-0.107 p=0.565	-0.043 p=0.820	-0.028 0.880	0.096 p=0.607	-0.188 p=0.310
SR: Accuracy	0.300 p=0.101	0.305 p=0.095	0.344 0.058	0.408 p=0.023	0.519 p=0.003	0.460 p=0.009	0.126 p=0.498	0.290 p=0.113	0.202 p=0.276	0.299 p=0.103
SR: Deviation	-0.347 p=0.056	-0.115 p=0.539	-0.516 p=0.003	-0.527 p=0.002	-0.521 p=0.003	-0.634 p<0.001	-0.199 p=0.283	-0.616 p<0.001	-0.445 p=0.012	-0.190 p=0.306
SR: NDB	-0.202 p=0.277	-0.093 p=0.619	-0.292 p=0.111	-0.473 p=0.007	-0.439 p=0.014	-0.511 p=0.003	-0.055 p=0.769	-0.546 p=0.001	-0.316 p=0.083	-0.182 p=0.328
TT: Accuracy	-0.230 p=0.213	0.193 p=0.299	-0.269 p=0.144	0.341 p=0.060	-0.158 p=0.395	0.489 p=0.005	0.218 p=0.240	0.211 p=0.254	-0.068 p=0.717	0.027 p=0.886
TT: Deviation	0.055 p=0.771	-0.160 p=0.390	-0.055 p=0.767	-0.488 p=0.005	-0.074 p=0.694	-0.626 p<0.001	-0.230 p=0.213	-0.332 p=0.068	-0.107 p=0.565	-0.099 p=0.595
TT: NDB	-0.072 p=0.701	-0.131 p=0.483	-0.003 p=0.986	-0.445 p=0.012	-0.167 p=0.369	-0.322 p=0.077	-0.219 p=0.237	-0.170 p=0.360	-0.080 p=0.668	0.123 p=0.510

p<0.05, p<0.01, p<0.001

Key:
MWL=Multisyllabic Word List
PR=Phrase Repetition
TT=Tongue Twisters
NWR=Nonsense Word Repetition
SR=Sentence Repetition
NDB=Number of Deviant Behaviours

For the SLI group, when repeating words containing complex articulatory sequences, phonological memory appears to play a bigger role in real word repetition, than nonsense word repetition. Thus, for the SLI group, poor performance on the SAB nonsense word task cannot be attributed solely to poor

phonological memory, but points to the influence of other factors. An inadequate mental syllabary (Levelt & Wheeldon, 1994) which aids phonological encoding; poor lexical knowledge (Gathercole & Baddeley, 1994), or poor speech motor abilities (van der Merwe, 1997) could contribute to this finding, which will be discussed further in the next chapter.

Auditory working memory (Sentence Questions) correlated with all MWL scores, and most SR and TT scores in the TD group, suggesting some involvement of working memory in these tasks. There are no correlations with NWR or PR. Similarly, the SLI group demonstrates correlations with SR and no correlations with PR. However, unlike the TD group, the SLI group shows no correlations with MWL or TT, but some correlations with NWR. The PR task may be too easy to require working memory processes, while the NWR task, which cannot draw on syntactic or semantic knowledge, is likely to involve immediate repetition, with no involvement of working memory. The differences between the groups with regard to correlations with MWL and TT tasks may suggest that the SLI group is relying on different underlying abilities when performing these speech tasks than the TD group. Their lexical knowledge may be too weak to use long term knowledge for the MWL task, resulting in immediate repetition, without the need to invoke working memory.

Rapid naming (Picture Naming) correlated with none of the speech tasks for the SLI group. In the TD group, there was a weak correlation with the Deviation score of NWR, and strong correlations with most SAB Sentence Repetition scores. A similar strong correlation was evident between the Picture Naming test and the CAS Sentence Repetition task (r_s=0.572, p=0.001) for the TD group, but no correlation between these measures for the SLI group (r_s=0.014, p=0.940). There thus seems to be a strong correlation between rapid naming and sentence recall of any type for TD participants, while no such relationship is seen for SLI participants. This difference may again suggest that the two groups rely on different underlying processes to complete the tasks.

Correlations among speech, language and memory scores were investigated further for SLI participants. Three patterns emerged. Firstly, Formulated Sentences, Word Series and the SAB Nonsense Word Repetition all

correlated with each other. This finding supports a successive processing component to both expressive syntax and nonsense word repetition. Secondly, receptive vocabulary (LV), repetition of multisyllabic words (MWL) and nonword repetition (CNRep) all correlated with each other. Correlations between vocabulary knowledge and nonword repetition have been well-documented (see previous discussions), and it has been shown that vocabulary knowledge stored in long term memory can impact on nonword repetition tasks, in terms of the "wordlikeness effect" (Gupta, MacWhinney, Feldman & Sacco, 2003). Vocabulary knowledge is also likely to impact on repetition of multisyllabic words, as prior knowledge of words in the test would reduce the processing demands and increase the likelihood of accurate responses. Thirdly, Formulated Sentences (FS), Sentence Questions (SQ), the SAB Nonsense Word Repetition (NWR) and the SAB Sentence Repetition task (SR-SAB) all correlated with each other. Syntactic knowledge would impact on performance on three of these tasks, FS, SQ and SR-SAB, thus it is not surprising that these tasks correlate. However, syntactic knowledge is not required for NWR. The SQ task assesses successive processing within working memory. It appears that the FS, NWR and SR-SAB tasks all require successive processing, and that they all place demands on working memory.

One of the hypotheses of this study is that poor speech production may constrain performance on complex linguistic tasks requiring verbal output. Results obtained on the phonological awareness task support this hypothesis. A second hypothesis is that linguistic knowledge stored in long term memory may impact on task demands in the SAB. In particular it was hypothesized that lexical knowledge may influence performance on the MWL, while syntactic knowledge (as well as lexical knowledge) would influence performance on tasks involving longer utterances (PR and SR). While there appears to be support for the hypothesis regarding lexical knowledge and single word speech tasks, it did not appear as if syntactic knowledge impacted on phrase and sentence tasks specifically. Instead, there appears to be a general correlation among the speech tasks and expressive syntax, which may point to common output factors affecting both types of tasks.

7.1.2 Summary of SAB Scores

Participants with SLI obtained significantly poorer Accuracy, Deviation and Number of Deviant Behaviours scores on all five speech measures than TD participants. The Accuracy scores indicate that, despite attempts to self-correct, SLI participants were significantly more likely to produce a final product that was incorrect. The Deviation and Number of Deviant Behaviours scores suggest that participants with SLI required greater effort to produce complex speech items, even if they were able to produce a correct final response. The effort required for speech production has implications for resource allocation within a processing limitations framework. This point will be explored further in the next chapter.

The SLI group took significantly longer to produce tongue twisters than the TD group. For the TD group, rate appeared to be correlated with structural problems noted on the OME. For the SLI group, rate appeared to be correlated with the number of attempts (revisions and repetitions) required to complete the task.

Participants with SLI thus presented with poorer speech production abilities than age-matched peers. The SLI group presented with a wider range of scores and some overlap with the TD group, suggesting that the SLI group is heterogeneous with regard to speech production abilities. Differences between the two groups were more apparent on Deviation and Number of Deviation scores, than on Accuracy scores.

Results obtained for all types of scores on all five tasks of the SAB provide support for the hypothesis that children with SLI have subtle and inconsistent speech production deficits, which may not be apparent on simple speech tasks, but which are evident on phonologically and motorically complex tasks which tax the speech production system. There is also support for the hypothesis that poor performance on the SAB cannot be attributed solely to linguistic or memory factors.

The fact that there is less overlap of scores between the two groups on the Deviation and the Number of Deviant Behaviours scores, provides support for the hypothesis that Accuracy scores alone are not sensitive enough to identify the

speech deficits of children with SLI. These results confirm the hypothesis that the Accuracy scores obtained by SLI participants may serve to overestimate their speech ability, as they produce correct responses only after hesitating, repeating or self-correcting some of these items.

The findings therefore also support the hypothesis that speech production is more resource-demanding for SLI participants than TD participants as more effort is required to produce a correct response. Such effort makes greater demands on available resources, as seen within a processing limitations framework. Deviation scores therefore appear to differentiate SLI and TD groups more clearly than the Accuracy scores. These results suggest that a simple right-wrong distinction is not sensitive enough when scoring responses on speech tasks for an adolescent population without overtly diagnosed speech disorders, and that Deviation or Number of Deviant Behaviours scores may more accurately distinguish performance between groups.

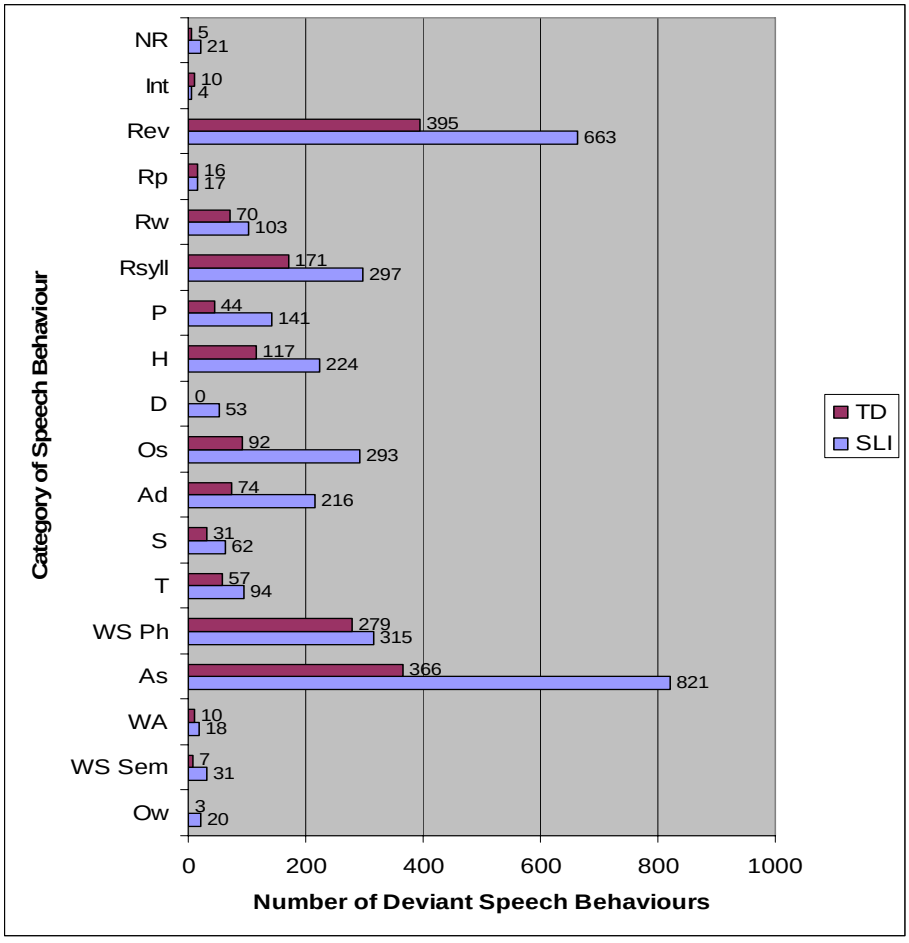
7.1.3 Analysis of Deviant Speech Behaviours

From the results presented above in 7.1.1, it is clear that there are quantitative differences between the SLI and TD groups on the SAB in terms of scores on all measures. The next question to answer is whether there are also differences with regard to the types of deviant speech behaviours used by the two groups. Deviant speech behaviours will be discussed according to the main categories described in Chapter 5, namely Sentence Level Deviations, Phoneme Substitutions, Syllable Structure Changes, Distortions, Fluency Deviations, Repetitions and Revisions, and Awareness of Deviations. Figure 7-3 reflects the number of deviant speech behaviours in each sub-category for the SLI and TD groups, while

Figure **7-4** reflects the overall proportions of the categories.

Overall, there did not appear to be substantial differences in terms of the types of errors used by the two groups. Both groups presented with a similar proportion of error types when looking at categories of errors, or individual error types. O'Hara and Johnston (1997 in Leonard, 1998) reported similar findings in analyzing syntactic errors, i.e. the error types of children with SLI were the same as those of control children, but more numerous. Similarly, Hill (2001), in a

review of limb praxis studies, found that children with SLI produce the same types of errors, but with greater frequency than their normally developing peers.



Key:

Ow=Word Omission
WA=Word Addition
WS-Ph=Phonetic Word Substitution
S=Substitution
Os=Sound Omission
H=Hesitation
Rsyll=Sound/Syllable Repetition
Rp=Phrase Repetition
Int=Interjection
WS-Sem=Semantic Word Substitution
As=Assimilation
T=Transposition
Ad=Addition
D=Distortion
P=Prolongation
Rw=Word Repetition
Rev=Revision
NR=No Response

Figure 7-3: Comparison of types of Deviant Speech Behaviours for SLI and TD groups.

Substitutions and Repetition/Revisions occurred most frequently (32-42% of deviations), followed by Syllable Structure Changes and Fluency Deviations (8-15% of deviations). Sentence Level Deviations, Distortions and Interjections

or No Responses had a negligible occurrence rate of 0-2%. Within the Substitution category, Assimilation and Phonemic Word Substitution errors were by far the most common, suggesting that errors were primarily influenced by the phonetic context of the utterance.

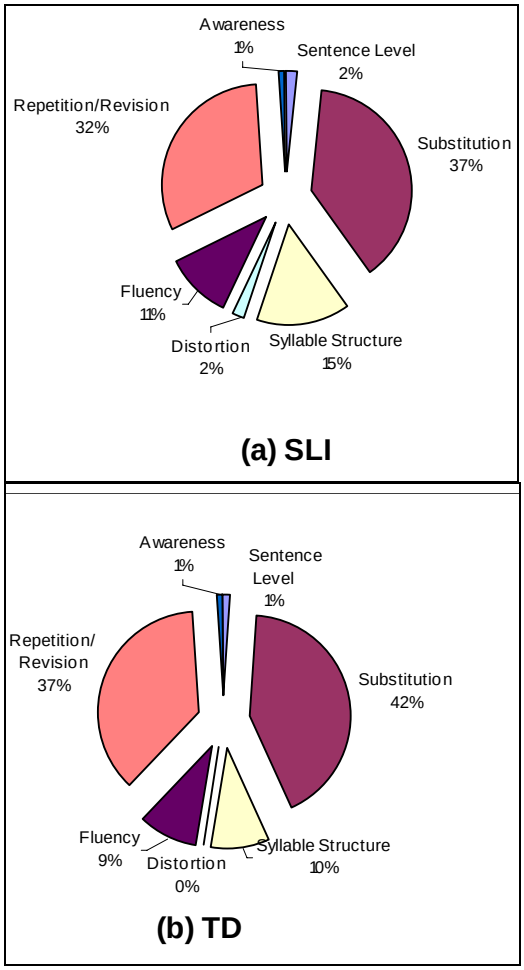


Figure 7-4: Contribution of Deviation categories to the total Number of Deviant Behaviours on the Speech Assessment Battery

Appendix P provides a detailed comparison of the categories of deviant speech behaviours by describing the mean occurrence, range and number of participants using each type of behaviour. Table 7-5 reflects the results of the Mann-Whitney Test, which compared the Number of Deviant Behaviours in each of the categories for the TD and SLI groups.

Table 7-5: Comparison of speech deviation categories (Mann-Whitney Test).

Category of Speech Deviation		Mann-Whitney Test
Sentence Level Deviations		**Ws=184.5; α<0.001***
	Word Omission	Ws=282; α<0.001*
	Semantic Word Substitution	Ws=289; α=0.002*
	Word Addition	Ws=411; α=0.202
Phoneme Substitution		**Ws=136.5; α<0.001***
	Assimilation	Ws=107; α<0.001*
	Phonemic Word Substitution	Ws=444; α=0.606
	Transposition	Ws=307; α=0.013*
	Substitution	Ws=278; α=0.003*
Syllable Structure Changes		**Ws=55; α<0.001***
	Addition	Ws=96; α<0.001*
	Phoneme Omission	Ws=115; α<0.001*
Distortion		**Ws=356.5; α=0.003***
Fluency Deviations		**Ws=165; α<0.001***
	Hesitation	Ws=249; α<0.001*
	Prolongation	Ws=244.5; α=0.001*
Repetitions and Revisions		**Ws=179; α<0.001***
	Syllable Repetition	Ws=217.5; α<0.001*
	Word Repetition	Ws=380; α=0.150
	Phrase Repetition	Ws=416.5; α=0.299
	Revision	Ws=186; α<0.001*
Awareness of Deviations		Ws=420.5; α=0.315
	Interjection	Ws=461; α=0.617
	No Response	Ws=385.5; α=0.074

p<0.05, p<0.01, p<0.001

Significant differences between the groups were found in all categories except Word Addition, Phonemic Word Substitution, Word and Phrase Repetitions, Interjections and No Responses. Differences were particularly notable in relation to Syllable Structure Changes, Assimilations, Syllable Repetitions, Revisions and Fluency Deviations.

Sentence Level Deviations

Sentence Level Deviations included Phoneme Omission, Semantic Word Substitution and Word Addition. With the exception of Word Additions, the SLI group used significantly more Sentence Level Deviations than the TD group. The SLI group was thus more likely to omit words or make semantic word substitutions. However, Sentence Level Deviations occurred infrequently in both groups (SLI=2% of deviations; TD=1% of deviations). Table 7-6 provides examples of deviations in this category.

Table 7-6: Examples of Sentence Level Deviations.

Category	Target	Deviation
Word Omission	*wristwatch*	*watch*
	wristwatch	*wrist*
	seashore	*shore*
Semantic Word Substitution	*Big black bug's blood.*	*Big black fly's blood.*
	The spy fled to Greece.	*The spy flew to Greece.*
	Sheep should sleep in a shed.	*Sheep should sleep in the shed.*
	Green glass globes glow greenly.	*Green glass globes glow quickly.*
Addition of Words	*Green glass globes glow greenly.*	*Green glass globes that glow greenly.*

Word Omissions: TD participants rarely omitted words (see Figure 7-3). Both groups appeared to find the Phrase Repetition task relatively easy, and did not omit words. On the two tasks requiring repetition of longer stimuli (Sentence Repetition and Tongue Twisters), several SLI participants omitted words. On the Sentence Repetition task, 16% of SLI participants omitted one or two words, while on the Tongue Twister task 35% of SLI participants omitted words, which is surprising in view of the fact that written and picture stimuli were available to aid recall on the latter task. There did not appear to be a direct link to performance on sequential memory tasks when comparing standard scores on the CAS Sentence Repetition task to number of words omitted. Thus, while SLI participants were more likely to omit words, this does not appear to be linked to their sequential memory abilities. The majority of the word omissions involved omission of part of a compound word (see Table 7-6) and did not affect the meaning of the sentence.

Semantic Word Substitutions: SLI participants were more likely to substitute semantically related words than TD participants. The highest number of semantic substitutions occurred on the Sentence Repetition task (39% of SLI participants and 16% of TD participants), possibly because there were no visual cues to aid recall. Only two participants had Semantic Word Substitutions on more than one task, confirming that this type of error was relatively rare. Semantic Word Substitutions did not affect the syntactic structure of the sentence, and usually retained the gist of the sentence.

Addition of Words: SLI participants had fewer errors in this category than in the other sentence level categories, and the two groups did not differ significantly with regard to this category. Words added by both groups were appropriate in terms of the syntax and semantics of the phrases or sentences.

The negligible occurrence of Sentence Level Deviations was to be expected, as this category of error is thought to reflect difficulties with linguistic-symbolic planning in terms of lemma retrieval. Since these citation tasks did not require much language formulation, it was anticipated that few sentence-level deviations would occur. These results are also similar to those reported by Edwards and Lahey (1998), who found that syllable deletion or addition was an infrequent error for both SLI and TD participants in their nonword repetition tasks, although SLI participants produced more such errors than TD participants.

Phoneme Substitutions

Phoneme Substitutions included assimilations resulting in nonsense words (Assimilation) or real words (Phonemic Word Substitution), Transpositions and Substitutions (not otherwise specified). The TD group used a greater proportion of Phoneme Substitutions than the SLI group, although the SLI group had a greater number of such substitutions. Substitution errors were the most frequently occurring type of error for both groups, with 37% of errors made by SLI participants and 42% of errors by TD participants being some form of phoneme substitution. These findings are consistent with other studies on speech errors, which have found that in Germanic languages (such as English), substitution errors occur more frequently than nonsubstitution errors (Meijer, 1997).

Errors influenced by context (Assimilations and Phonemic Word Substitutions) were the most common type of substitution, which is similar to results reported by Wilshire (1999) regarding tongue twister performance in normal adults. Both groups produced a similar proportion of Transposition and Substitution errors, but differences in terms of total number of errors in each category were significant.

The primary difference between the two groups appears to be with regard to their use of assimilatory errors. There is a significant difference between the

groups with regard to use of Assimilations, while there is no difference in terms of number of Phonemic Word Substitutions. Edwards and Lahey (1998) also reported no differences between SLI and TD groups in terms of substituting real words for intended words. In studies on nonword repetition, it has been found that children tend to change nonwords into real words (e.g. Ellis Weismer & Hesketh, 1996; Edwards & Lahey, 1998). One possible explanation for this tendency is the possibility that children may use familiar underlying representations when attempting to hold novel phonetic sequences in working memory (Gathercole & Adams, 1994 in Edwards & Lahey, 1998), either to aid storage in working memory, or by relying on familiar representations to form phonological representations for unfamiliar or long sequences (Edwards & Lahey, 1998). Alternatively, a postlexical editor during phonological encoding has been postulated for such a lexical effect (Levelt, 1992).

SLI participants produced more assimilatory errors resulting in nonsense words. This finding may suggest that TD participants have more effective postlexical editors; or it may suggest that TD participants are better able to use familiar underlying phonological representations to aid performance on speech output tasks.

Assimilation: Assimilatory errors resulting in nonsense words were the most common type of error produced by SLI participants as 821 of their 3405 errors (24%) were Assimilations. Both groups produced more Assimilation errors than Phonemic Word Substitutions, however the proportion of errors was markedly different. For SLI participants, the ratio of Assimilations to Phonemic Word Substitutions was 2.61:1, while for TD participants it was 1.31:1. Thus, when making assimilation errors, SLI participants were twice as likely as TD participants to produce nonsense words, rather than real words. This finding has important implications for the SLI participants' ability to monitor their speech output, and will be discussed further in the next chapter.

Assimilation errors were influenced by place of articulation, manner of articulation and voicing (see Table 7-7), although place of articulation errors were by far the most frequent. This is consistent with findings by Shattuck-Hufnagel and Klatt (1980) who studied a large corpus of naturally occurring

speech errors. Some errors involved changes to both place and manner of articulation. Errors were both anticipatory and perseverative. The Tongue Twisters yielded the highest occurrence of Assimilation errors for both groups, with all participants in both groups producing at least one Assimilation error in this task. This result was to be expected, as tongue twisters are designed to elicit this type of error (Wilshire, 1999).

Table 7-7: Examples of Phoneme Substitutions.

Category	Target	Deviation
Assimilation	*emphasis*	*emphanis; emphafis*
	symphony	*syn[ɵ]ony; synphony*
	sea	*she*
	wristwatch	*wristwats*
	badly	*bably*
	aluminium	*alumilium*
	enthusiasm	*esthusiasm*
	bright	*blight*
	susceptible	*suscestible*
Phonemic Word Substitution	*Blue plaid pants.*	*Blue plan pants.*
	The spy fled to Greece.	*The fried fled to Greece.*
	Wash each dish twice.	*Watch each dish twice.*
	Six slim sailors.	*Sick slim sailors.*
	Santa's short suit shrunk.	*short→sort, suit→shoot, shrunk→trunk*
	She sells seashells by the seashore.	*she→sea, sells→shells, shore→sore*
	Green glass globes glow greenly.	*glow→grow, glass→grass*
	Red lorry, yellow lorry.	*red→led, lorry→lolly*
	Which wristwatch is a Swiss wristwatch.	*which→rich, wristwatch→richwatch wristwatch→whichwatch wristwatch→wishwash*
Transposition	*thumbtacks*	*tumthacks*
Substitution (not specified)	*The spy fled to Greece.*	*[də] spy fled to Greece.*
	Tom wears shoes.	*Tong wears shoes.*

Phonemic Word Substitutions: For both groups, this was the third largest category of errors (SLI=315 errors; TD=279 errors), making up 9% of SLI errors and 16% of TD errors. The fact that the two categories of assimilatory errors make up two of the three largest error categories, indicates that for both

groups the phonetic context of the target utterance largely influenced their errors, but that for TD participants, syntactic and semantic factors also played a role.

Phonemic Word Substitutions were rare in the single word tasks, as few real words have a similar structure to the multisyllabic words used in these tasks. However, this type of error was common in the Phrase, Sentence Repetition and Tongue Twister tasks.

As with the Assimilation errors analysed above, the Phonemic Word Substitutions involved errors of manner of articulation and place of articulation. Since none of the items emphasized voicing contrasts, errors involving voicing were rare. Errors were both anticipatory and perseverative in nature.

Compared to the other types of substitution errors, Transpositions and Substitutions (not otherwise specified) made up a very small proportion of errors.

Transpositions: Transposition errors made up only 3% of overall errors in both groups, and thus did not appear to contribute substantially to the total Number of Deviant Behaviours. On single word tasks, SLI participants produced substantially more Transpositions than TD participants, but there was much less difference between the groups on tasks that were longer than a single word. There are three possible explanations for this result. Firstly, as was discussed in earlier sections, children with SLI are more likely to have vocabulary deficits. It is thus possible that many of the multisyllabic words were unfamiliar to the SLI group, and that they were unable to use information stored in long term memory to aid their production of these words. The Phrase, Sentence and Tongue Twister tasks involved much simpler vocabulary items, which may have allowed participants to use lexical knowledge stored in long term memory to monitor their output. Secondly, utterances longer than a single word contain syntactic and semantic information which would enable a participant to monitor output more effectively in terms of whether it made sense, than would be possible in single word tasks. Transpositions were more likely to result in nonsense words. When producing multi-word utterances such nonsense words would be avoided, as it would compromise the message conveyed by the utterance. Thirdly, multisyllabic words are more complex to produce in terms of the motoric demands, which may result in more Transpositions.

Substitutions (not otherwise specified): For both groups of participants, substitution errors which were not assimilatory or transpositions made up 2% of the total errors, with SLI participants having more substitutions on single word tasks and Sentence Repetitions than TD participants. On Phrase Repetition and Tongue Twister tasks their performance was almost equivalent in terms of mean number of substitutions.

The fact that the TD group used proportionally more substitution errors than other types of errors, may suggest that when they make errors, they attempt to retain the syllable structure of the stimulus.

Syllable Structure Changes

Additions or Omissions of Phonemes were classified as changes to syllable structure. The SLI group made a higher proportion of changes to syllable structure than the TD group, as well as more Syllable Structure Changes overall (15% of total deviations) than TD participants (10% of total deviations). Both groups omitted phonemes more frequently than they added phonemes. The SLI group was particularly prone to omitting phonemes.

Changes to syllable structure may be the result of a short term memory deficit, where the stimulus is recalled incorrectly, poor specification of a syllable frame during phonological encoding, or a difficulty with motor planning during speech production.

Additions: For each task (with the possible exception of Phrase Repetition) SLI participants presented with a higher mean number of phoneme Additions, and more SLI participants presented with Additions than TD participants. There was only one instance of a vowel being added, while the rest of the errors involved consonants (see Table 7-8). Furthermore, there were few instances of a syllable being added. All other instances of Addition involved the addition of a single consonant, which resulted in the creation of a new consonant cluster, or added another consonant to an existing consonant cluster. In the case of the single word tasks, the addition of phonemes changed multisyllabic words into nonsense words. In the phrase, sentence and tongue twister tasks, some Additions also resulted in nonsense words, or real words which changed the meaning of the sentence. However, some errors involved the addition of

phonemes that could be regarded as grammatical morphemes, which therefore did not change the meaning of the sentences substantially (for example, *brown→brown[d])*.

Table 7-8: Examples of Syllable Structure Changes.

Category	Target	Deviation
Addition of Phonemes	*physicist*	*physic[sə]cist*
	greenly	*greeningly*
	consequence	*conse[n]quence*
	suspicious	*S[p]uspicious*
	synthesis	*synthesis[t]*
	especially	*E[k]specially*
	consciousness	*consciou[n]sness*
	beam	*b[l]eam*
	pea	*[s]pea*
	flounders	*flounde[re]rs*
	band	*b[r]and*
	badly	*b[r]adly*
	brown	*brown[d]*
	blue	*blue[d]*
	pea	*pea[d], pea[z]*
Omission of Phonemes	*statistics*	*S_atistics*
	probably	*proba_ly*
	claw	*c_aw*
	black	*_lack*
	blue	*b_ue*
	green	*gree_*
	shining	*shini_*
	plaid	*p_aid*
	bread	*b_ead*

The addition of phonemes may reflect the participants' weak phonological memory abilities, where the Addition errors were the result of the manner in which the responses were elicited (repetition); but may also reflect poorly constructed syllable frames or poor speech planning.

Omissions of Phonemes: The SLI group made substantially more Phoneme Omission errors than the TD group, both in terms of mean Number of Deviant Speech Behaviours, and number of participants presenting with the error type (see Appendix P). Omission errors usually involved the omission of a consonant in a consonant cluster (see Table 7-8), although single consonants were occasionally affected.

Similar to findings reported by Edwards and Lahey (1998), both groups tended to substitute, rather than omit phonemes. This pattern of results is somewhat similar to that reported by Wilshire (1999) in normal adults, who produced predominantly substitution errors in tongue twisters, rather than additions or omissions.

There are several possible explanations for omission errors. Firstly, omissions may be related to poor auditory memory. Edwards and Lahey (1998) interpreted substitutions as suggesting that every phonetic segment had a phonetic representation in the working memory; while omission errors reflect difficulty in holding detailed phonological representations in working memory. In their view, the error patterns in the current study are more suggestive of difficulties with phonological representation, than working memory. Secondly, one may argue that when consonants are produced as part of a cluster, the phoneme duration is shorter (Clark & Yallop, 1990), and hence the difficulties that children with SLI have in discriminating phonemes of short duration (Tallal, 1990), could have resulted in omission errors. However, as many of the errors involved the omission of the longer consonant in a cluster (for example, *blue→b_ue)*, this explanation cannot account for all the errors. Thirdly, omissions may reflect inadequate syllable frames. However, in view of the nature of these tasks (repetition), this explanation is unlikely. Finally, the complex coordination required in producing a consonant cluster, may have resulted in simplification errors, and the errors may thus reflect poor motor speech abilities (van der Merwe, 1997). During speech development, phonemes or syllable structures which are motorically difficult to produce are often affected by omission, which may reflect difficulties with speech output, rather than phonological representations. In the Edwards and Lahey study, the participants were relatively young (mean age 6.11 years), suggesting that speech development was not complete, and that omission errors might have been influenced by speech output factors. In the current study, speech output factors are the most likely reason for both the omission and substitution of phonemes.

Distortions

SLI participants produced 53 distortions (2% of their total deviations), while no TD participants produced distortions. Distortion errors were rare even within the SLI group, as there were only a few (n=5) participants who produced any distortions. Distortion errors appeared to be closely linked to structural and functional aspects of the articulators, as the participants who produced Distortions generally also presented with malocclusion and/or tongue thrust. There is a possibility that Distortions may be related to resource allocation, in that speakers could compensate for structural or functional abnormalities of the articulators under some conditions, but may not be able to maintain this compensation when resource demands increase. However, there is insufficient evidence to support this hypothesis at this time.

Fluency Deviations

Hesitations and Prolongations were classed as fluency errors.

Table 7-9: Examples of Fluency Deviations.

Category	Target	Deviation
Hesitation	*chivalry*	*chi-valry*
	Mixed biscuits	*m-ixed biscuits*
	Brown and blue plaid pants	*Brown and blue – plaid pants*
	Bright blue beam	*Bright blue – beam*
Prolongation	*statistics*	*sstatistics*
	statistician	*Sstatistician*
	Sam shines shoes	*Sam shines shoes*
	fine fruit flies	*ffine fruit flies*
	Have some fried flounders.	*Have some ffried flounders.*

Hesitations: Hesitations within or between words comprised 7% of errors for both TD and SLI groups. The SLI group used significantly more Hesitations as they presented with a higher mean number of Hesitations, and more SLI participants used Hesitations than TD participants (Appendix P). Since the proportion of Hesitations remained constant across the two groups, it is likely that Hesitations are related to the overall Number of Deviant Speech Behaviours. That is, the more deviations that occur, the more likely a participant is to hesitate. Hence the SLI group were expected to present with a higher number of Hesitations.

Hesitations appeared to be anticipatory, that is occurring just before a complex sequence of phonemes (see Table 7-9 for examples) or immediately after a difficult sequence. In both instances, the hesitations appear to suggest some form of self-monitoring. In the case of anticipatory hesitations, it is possible that the participant is hesitating to ensure that the motor plan he/she has formulated, is correct (van Der Merwe, 1997). This view is in accordance with Jarrold, Hewes and Baddeley's (2000) view that pauses between words provide a potential index of selection, retrieval or planning processes required for the articulation of an utterance. Since selection and retrieval are of negligent importance in a repetition task, these hesitations are likely to reflect planning. In the case of hesitations occurring after difficult sound sequences, it is possible that monitoring is occurring both to evaluate the accuracy of the phonemes already produced, and to evaluate the accuracy of the remaining planned sequence (feedback and feedforward). Planning of a word can occur during articulation of a previous word (Sternberg et al, 1978 in Jarrold et al, 2000), while articulation of a word can also begin before the word has been entirely planned (Bachoud-Lévy et al, 1998, in Jarrold et al, 2000).

In both the case of hesitations preceding or following difficult sequences, it is probable that the participants are aware of the potential of producing errors. An additional explanation for the high number of hesitations in the SLI group, is that perhaps their processing limitations are affecting their speed of processing, and that they are hesitating to allow additional time for processing (both in terms of perceiving the stimulus to be repeated, and in formulating the appropriate motor output).

Prolongations: Prolongations are generally regarded as being typical of stuttering (Enger, Hood & Shulman, 1988). However, both SLI and TD participants (who were not regarded as stutterers) used Prolongations. SLI participants used marginally more Prolongations (4%) than TD participants (3%). Few vowel prolongations were noted. In most instances, Prolongations involved consonants which were part of difficult articulatory sequences (see Table 7-9). Participants appeared to be using Prolongations to provide additional processing time. As with Hesitations, Prolongations occurred in positions which suggest

that participants were using the time provided by the prolongation to monitor preceding utterances, or to plan the following phoneme sequence.

Both Prolongations and Hesitations thus appear to be used as strategies to aid self-monitoring or planning.

Repetitions and Revisions

Sound and part-word repetitions[39], Word Repetitions, Phrase Repetitions and Revisions were included in this category[40]. The TD group used proportionally more repetitions and revisions (37%) than the SLI group (32%), but the SLI group used a significantly higher number of repetitions and revisions (see Figure 7-3).

Table 7-10: Examples of Repetitions and Revisions.

Category	Target	Deviation
Syllable Repetition	*associate*	*associ-associ-associate*
	exclamation	*ex-exclamation*
	flies	*f-flies*
	He likes split pea soup.	*He likes split pea sou-soup.*
	Green glass globes glow greenly.	*Green glass globes gl-glow greenly.*
	Have some fried flounders.	*Have some fried frou-frounders.*
Revision	*consciousness*	*conscience-consciousness*
	Quiet crabs claw.	*Quiet crabs c_aw-claw.*
	Bright blue beam.	*Blight-bright blue beam.*
	Six slim sailors.	*Six slim slai-sailors.*
	synthesis	*syn-[ɵ]ynthesis*
	Blue plaid pants.	*Blue[d] pa- blue[d] pa-plan pants.*
	skeptical	*Step-sep-se-s_eptical*

Syllable, Word and Phrase Repetitions: Although there were differences in terms of the mean number of repetitions and the number of participants using repetitions, the overall proportion of repetitions in relation to total errors was very similar for the two groups.

The use of Word and Phrase repetitions did not differ between the two groups, particularly with regard to the number of participants using these repetitions (see Appendix P). Syllable Repetitions were used significantly more

[39] Sound and part-word repetitions were grouped together as *Syllable Repetitions*, and are usually regarded as being typical of stuttering (Enger, Hood & Shulman, 1988).

[40] Repetitions referred to any exact repetition of a preceding utterance. Repetitions therefore did not necessarily involve the repetition of a correct utterance. Revisions referred to any attempt to correct a previous utterance, at sound, syllable, word or phrase level, and did not necessarily result in a correct response.

by SLI participants, and as with the Prolongations and Hesitations discussed above, occurred most frequently in the more difficult parts of words (see Table 7-10). In previous studies Syllable Repetitions have been regarded as an attempt to express increasingly complex thoughts and grammatical forms (Enger, Hood & Shulman, 1988). However, in this study Syllable Repetitions may reflect difficulty in producing more complex or motorically demanding phonological forms. In contrast to the Hesitations and Prolongations, which could occur in any word position, Syllable Repetitions occurred primarily in word initial position. This is consistent with findings in the literature on stuttering (Guitar, 1998), where dysfluencies are reported to occur primarily at the beginning of words. However, in the stuttering literature dysfluencies are thought to occur primarily at clause boundaries (Enger, Hood & Shulman, 1988), which was not the case in this study. The most likely explanation for this finding, is that phonological and motoric complexity, rather than syntactic complexity, was influencing dysfluencies; hence dysfluencies would occur in loci of phonological or motoric complexity, rather than at clause boundaries.

Repetition errors appeared to indicate some involvement of monitoring strategies (possibly controlled by mechanisms such as the central executive), where participants were attempting to gain additional time for processing before producing a difficult phoneme sequence, or wanted to monitor whether their production of a difficult sequence was correct (see Table 7-10 for examples). SLI participants were much more likely to use this strategy than TD participants.

Revisions: Revisions were one of the two most commonly occurring errors. SLI participants used significantly more Revisions than TD participants. It is important to note that where a participant made an assimilation error, which he/she then attempted to correct, this was coded as two errors (Assimilation + Revision) or even three errors (Assimilation + Revision + Assimilation), if the revised version still contained an error. It is thus not surprising that the Revision and Assimilation categories were similar in size, as these two errors often co-occurred. Three patterns of errors were noted with Revisions. An incorrect response could be revised to be correct; occasionally a correct response could be revised to become incorrect; or a participant could make multiple attempts to

produce the correct response, but merely substitute one error for another (see Table 7-10 for examples).

The fact that participants made so many attempts to correct their speech output, points strongly to a breakdown of speech motor planning rather than a breakdown of phonological encoding or storage. Attempts to correct output suggest that participants had more accurate codes in their phonological memory than was reflected in their output (Catts, 1986; Wilshire, 1999). In the Tongue Twister task individual errors rarely perseverated from one repetition to the next, indicating that participants were not merely repeating an incorrectly stored representation, but were matching their output against an external target (similar to findings reported by Wilshire [1999]).

Revisions clearly only referred to audible speech output, and can be regarded as evidence of self-monitoring during speech production. However, it is entirely likely that, as suggested by van der Merwe (1997), feedback loops during the speech production process result in "revision" occurring before a response is actually produced. Hesitations and Prolongations could represent periods when a child is making revisions to his/her planned output, without having to produce the output first (feedforward). The fact that the TD group used proportionally more Repetitions and Revisions than the SLI group may suggest that they were more aware of potential errors and made more attempts to self-correct.

Awareness of Deviations

Interjections and items coded as No Responses were felt to indicate a measure of awareness of the difficulty of items. There was no significant difference between the two groups on either Interjections or No Responses, but both categories of deviation had negligible occurrence rates of 0-1%.

No Responses included refusals, requests for repetition of stimuli, or items which were abandoned before producing sufficient output for analysis. The infrequent occurrence of No Responses may be related to the participants' age and the apparent simplicity of the task. For 13-year old participants, the stimuli used in this study did not appear excessively difficult. Where difficulty was encountered, participants appeared more likely to make multiple attempts to

produce the stimulus (repetitions and revisions), than to refuse or abandon an item. Infrequent requests for repetition of stimuli may also reflect that participants perceived this task to be easy.

Interjections occurred rarely, possibly because the tasks involved citation, rather than spontaneous production.

Summary of Types of Deviant Speech Behaviours

Compared to TD participants, deviant speech behaviours produced by SLI participants differed not only in terms of quantity, but also quality. Although both groups primarily produced assimilatory errors, SLI participants were more likely to produce nonwords than TD participants. SLI participants also produced proportionally fewer repetitions and revisions. Both of these findings are suggestive of impaired monitoring of speech production.

7.2 Comparison of Neuromotor Abilities

The second aim of the study was to determine if adolescents with SLI present with subtle neuromotor deficits that could impact on speech production. Results from the Oral Motor Evaluation (OME) will be presented first, to indicate whether adolescents with SLI have functional abnormalities of the articulators independent of linguistic factors. Thereafter participants will be compared with regard to their history of motor deficits in non-speech domains.

7.2.1 Performance on the Oral Motor Evaluation (OME)

The Oral Motor Evaluation consisted of three components, namely Structure, Function and Speech Function. Participants with SLI presented with significantly poorer Function and Speech Function ratings than the TD group, while Structure ratings did not differ significantly between the two groups.

Results for the 91-item checklist will be presented as follows: The two groups' performance on each component will be compared. Thereafter the problematic items within the three components will be discussed and compared for the SLI and TD groups.

Comparison of OME Ratings

Table 7-11 below compares the mean Oral Motor Evaluation (OME) ratings, ranges and standard deviations of the TD and SLI groups. Ratings reflect the number of problematic areas on the checklist.

In all three areas of the OME, i.e. mean Structure, Function and Speech Function ratings, the SLI participants presented with more problematic areas than the TD participants. Using the Wilcoxon Scores (Rank Sums) two sample test, Speech Function ratings were found to be significantly different (T=0.0193), while Structure ratings were not significantly different (T=0.0919). Since Function ratings showed minimal variability, a Chi Square test was used to evaluate differences, where all ratings of 2 and over were treated as one category. Results indicated significant differences between the two groups on Function ratings (X^2=0.0027). In terms of clinical significance, the differences between the two groups are small, yet the differences in Function and Speech Function ratings were statistically significant. These results suggest, that even without the added burden of producing linguistic output, the SLI group experienced more difficulty with oral and articulatory functions, than the TD group.

Table 7-11: Comparison of OME ratings: Mean rating, range and standard deviation (*SD*) of Structure, Function and Speech Function ratings.

		Structure	Function	Speech Function
SLI	***Mean (SD)***	2.19 (1.74)	1.10 (0.94)	3.35 (1.98)
	Range	0-7	0-3	0-8
TD	***Mean (SD)***	1.52 (1.57)	0.39 (0.76)	2.19 (1.28)
	Range	0-6	0-3	0-5

The absence of structural differences between the two groups was to be expected. By definition, children with SLI should not present with oral structural anomalies (Leonard, 1998), and they were therefore not expected to differ markedly from their TD peers in this regard. Results for the Function and Speech Function components are similar to those found by Tallal et al (1989 in Leonard, 1998), which suggested that children with SLI have difficulty with rapid repetitive oral movements.

Both groups presented with a similar range of ratings, although the SLI group had a higher maximum rating for both Structure and Speech Function. In both groups, there were some participants who obtained ratings of 0 (ten TD participants and five SLI participants). Both groups presented with relatively small standard deviations in all areas, although the TD group appeared to have slightly less variability of ratings than the SLI group. The similarity in range of ratings suggest that, while there are group differences on the Speech Function and Function ratings, there is much overlap of individuals within the two groups. Thus, SLI participants are more likely to have poorer ratings, but individuals may have excellent ratings. These results confirm yet again the heterogeneity of the SLI population, and perhaps point to subgroups of SLI which can be differentiated on the basis of their oral motor abilities.

OME Components: Problematic Items.

Each component will be discussed by providing a table indicating the areas found to be problematic in each group, as well as the number of participants who obtained error ratings for particular items. A detailed description of participants' performance on the OME is provided in Appendix Q. It is important to remember that one deviancy in the oral area does not necessarily cause disordered speech (Haynes & Pindzola, 2004). However, within a resource-limited system, such deviancies could have an additive effect to influence speech production on tasks that are resource-intensive.

Structure: As can be seen in

Table 7-12, there were few structural areas, where TD participants obtained worse ratings than SLI participants and in most cases these differences were negligible. Compared to TD participants, SLI participants obtained markedly poorer structural ratings as a result of malocclusion of the mandible (overbite), decayed or missing teeth, structure of the velopharynx (excessively long uvula), and slouched posture. The slouched posture is indicative of low muscle tone, which is regarded as a soft neurological sign (Brown and Minns, 1999). As the differences in structural ratings did not reach statistical significance in these two groups, this area will not be discussed further. However, since SLI participants did receive poorer ratings than TD participants,

this area may bear further investigation. If some subtypes of SLI are of genetic origin, as has been discussed previously (e.g. Bishop & Bishop, 1998; Tomblin & Buckwalter, 1998; Flax et al, 2003), it is conceivable that physical features may be inherited in addition to the linguistic and/or information processing deficits that are characteristic of SLI. A more rigorous evaluation of physical features of children with SLI may identify subtle differences not previously detected.

Table 7-12: Comparison of number of participants with poor ratings on Structure items.

Item		SLI	TD
LIPS	Symmetry	1	-
	Relationship of lips at rest	2	1
	Muscle tone	1	-
MANDIBLE	Symmetry	1	1
	Occlusion	6	3
	Size	1	-
MAXILLA	Size	1	-
TEETH	Decay	5	1
	Alignment	9	9
	Gaps	3	4
	Missing	8	-
	Occlusion	1	4
TONGUE	Structure and carriage	3	3
	Furrowing	8	6
	Size	1	-
PALATE	Structure	1	2
VELOPHARYNX	Symmetry	5	6
	Structure	5	2
	Size velum:pharynx	3	1
POSTURE		7	3
FACIAL FEATURES		1	-

Function: All participants were able to perform basic functions of the articulators (see Table 7-13). SLI participants obtained notably poorer ratings than TD participants in several areas, while in no area did TD participants perform worse than SLI participants. Differences were noted in terms of alternating lip protrusion and retraction, dissociation of the tongue and mandible, external elevation of the tongue, and slow circumoral movement of the tongue. These findings are in agreement with a study on limb praxis, which found that children with SLI could learn individual movements in a sequence, but had

difficulty with the planning, integration and/or execution of a combination of postures into a sequence (Dewey et al, 1988, in Hill, 2001).

With the possible exception of external tongue elevation, the other areas of difficulty are all complex movements requiring a high degree of neurological control and coordination. All these behaviours were elicited using imitation, with the obvious exception of the respiration item. The statistically significant differences in Function ratings therefore suggest that SLI participants have poorer control of their articulatory system on tasks that are free of linguistic or processing demands. Crary (1993) in a review of a number of studies involving adults and children concluded that there was some neurological relationship between nonspeech oral movements and speech production. It can therefore be anticipated that children with poor Function ratings may have poor speech production abilities.

Table 7-13: Comparison of number of participants with poor ratings on Function items.

Item		SLI	TD
LIP	Rounding	1	-
	Alternate pucker/smile	4	1
TONGUE	Dissociation from mandible	9	4
	Elevation to alveolar ridge	4	3
	External elevation	9	2
	External lateralization	1	-
	Slow circumoral movement	5	1
RESPIRATION		3	-

It should be noted that the Function section of the OME contained the smallest number of items (19 items, as opposed to 28 Structure and 44 Speech Function items) and that only a small proportion of problematic areas on the OME were related to Function, suggesting that these results should be interpreted with caution. It is possible that too few Function items were included on the checklist to assess this area in sufficient depth.

Speech Function: As was expected, both TD and SLI participants could perform basic speech function tasks, such as production of single phonemes, with ease (again in agreement with findings by Dewey et al [1988, in Hall, (2001)] regarding learning of individual movements versus sequences of limb

movements). Both groups experienced difficulty with sustained repetition of multisyllabic words (see Table 7-14). When the words "buttercup" and "petticoat" had to be repeated four times, or as many times as possible, several participants in both groups struggled. These tasks require a high degree of coordination and sequencing, and are thus likely to be difficult for participants whose articulatory and neurological systems are still developing. However, despite the developmental demands of these tasks, it was apparent that SLI participants struggled more than TD participants. Since none of the participants had difficulty saying the words once, it is clear that the difficulty with these words does not lie with the production of specific speech sounds, nor even with the production of multisyllabic words per se. Instead, the difficulty appears to arise when words have to be repeated in succession, placing high demands on sequencing and rapid and sustained movements of the articulators.

Table 7-14: Comparison of number of participants with poor ratings on Speech Function items.

Item		SLI	TD
LIPS	Alternating /u/ -/i/	2	-
TONGUE	Lateral edges to teeth "sh"	1	-
	Vowel (mid)	1	-
	Interdental "th"	-	1
RAPID REPETITIONS	"pepe"	1	-
	"tete"	1	-
	"keke"	1	-
	"peteke"	6	4
	"Buttercup" x4	5	2
	"Buttercup" sustained	21	16
	"Petticoat" x4	2	-
	"Petticoat" sustained	17	4
PROSODY	Rate	2	2
VOICE	Pitch	1	1
	Loudness	5	5
	Quality	6	3
	Voice stoppages	2	1
	Phonation duration /a:/	7	10
	Duration /s/	2	8
	Duration /z/	3	4
	s:z ratio	-	3
RESONANCE	Nasal resonance	4	3
INTELLIGIBILITY		9	2

It is of interest to note that more TD participants experienced difficulty on the items evaluating duration of /s/ and /a/. There is no clear explanation for this result. The difference may be an artifact of testing, particularly as the differences are small.

In terms of overall intelligibility rating, SLI participants fared worse than TD participants, with 29% of SLI participants, and only 6.4% of TD participants receiving poor intelligibility ratings. While some of these poor intelligibility ratings may have been related to the presence of dental braces, tongue thrust or structural abnormalities, most of the participants with poor intelligibility ratings also had overall poor Speech Function ratings and presented with features which could be regarded as "soft" neurological signs. At the same time, some participants with poor Structure ratings did not have poor intelligibility ratings. The question thus needs to be asked why some children are able to compensate for structural defects, producing adequate speech, while others cannot. One possible explanation is that the extent of the structural defects may play an important role. The checklist used in the current study allowed the researcher to record only the presence or absence of problematic features. A future study may need to develop a graded instrument, which allows each feature to be rated in terms of severity. A comparison can then be made of severity of deficits to the intelligibility rating. Other explanations may have to do with the presence of "soft" neurological signs and/or resource allocation, which may affect the participants' ability to compensate for structural abnormalities. This possible explanation will be explored further in the discussion section.

The differences between the two groups with regard to Function and Speech Function ratings thus support the hypothesis of this study, that children with SLI have subtle oral motor coordination deficits which affect their oral function. The Speech Function findings in particular support the hypothesis that children with SLI have difficulties with the neuromotor coordination of complex speech movements. These results further support the hypothesis that the screening measures for oral motor function that are used routinely to establish candidacy for SLI studies (e.g. Robbins and Klee, 1987), are not sufficiently sensitive to identify the subtle deficits with which this group presents.

From the above results, it is apparent that oral and speech movements which placed higher demands on neuromotor coordination of the articulators, proved to be particularly difficult for the SLI group, thus supporting the hypothesis that children with SLI have difficulties in this area. Many of the Function and Speech Function deficits were similar to developmental signs regarded as "soft" neurological signs, such as associated movements, dysdiadochokinesia and difficulty with alternating movements (Brown & Minns, 1999), suggesting a neurological basis for these difficulties.

7.2.2 History of Motor Coordination Difficulties

Results of the risk factor questionnaire were coded using the categories and criteria listed in Appendix I. Participants who were reported to have a history of fine or gross motor deficits, or who had received Occupational Therapy for motor deficits, were included in the category of motor coordination difficulties, which will be discussed below. As described in Chapter 6, risk factors were considered primarily in relation to a Poor Speech group. This group of 23 participants formed a subset of the SLI group, and consisted of participants who obtained a total Number of Deviant Behaviours score that was more than 2*SD* above the TD group's mean of 56.3 (SD=18.5). Appendix R provides raw data on this group. From Figure R1 in Appendix R it is apparent that apart from three outliers, all TD participants obtained 80 or fewer errors on the SAB. The cut-off of 94 used to identify the Poor Speech group, is thus a conservative measure. Had the lower cut-off of 80 been used, three more participants with SLI would have been added to the Poor Speech group.

In comparison with the TD group, a large number of SLI participants presented with a history of motor disorders, with a similar large percentage of the Poor Speech group reporting motor difficulties.

Of the participants with SLI, the majority had attended Occupational Therapy, although some had received therapy for visual perceptual deficits, rather than motor deficits. Nineteen (61.3%) of the participants with SLI reported specific fine and/or gross motor deficits, or described difficulties with handwriting and/or low muscle tone. Seven (22.6%) TD participants reportedly had difficulty with fine and/or gross motor coordination, or had low muscle tone.

Only four TD participants had attended Occupational Therapy to address these deficits. The participants with SLI thus were much more likely to have motor deficits, which was not unexpected in view of previous findings in the literature (Leonard, 1998; Hill, 2001).

Table 7-15: Number of participants with motor coordination difficulties: Comparison of SLI, Poor Speech Group and TD participants.

	Motor Coordination Difficulties	No Reported Motor Coordination Difficulties	No Information
SLI (n=31)	23 (74%)	4 (13%)	4 (13%)
SLI Poor Speech Group (n=23)	18 (78%)	1 (4%)	4 (17%)
TD (n=31)	8 (26%)	23 (74%)	0

Table 7-15 compares the SLI and TD groups with regard to motor deficits. Participants with SLI were three times more likely than TD participants to have some history of motor coordination difficulties. All but one of the participants with a history of motor difficulties had attended Occupational Therapy. Fine motor difficulties were reported for 17 of the 23 SLI participants with motor deficits, and gross motor difficulties for 8 of these 23 participants. One participant also reported low muscle tone. It should be emphasized that many caregivers indicated that they were not sure why their children attended Occupational Therapy, thus the numbers presented in the previous sentence may underestimate the numbers of participants in these categories. These results are in agreement with previous studies by Stark and Tallal (1981b), Tallal et al (1989, in Redmond & Rice, 1998), and Swisher, Plante and Lowell (1994), that children with SLI may have concomitant motor deficits. Results are very similar to those reported by Kovac, Garabedian, Du Souich and Palmour (2001), who found that 79% of their SLI participants had mild neurological symptoms (fine motor problems, coordination/balance problems, immaturity, motor delay, minimal cerebral dysfunction, slight hypotonia). Results of the current study may support Paul and Fountain's findings (1999 in Law, Boyle, Harris, Harkness & Nye, 2000). After following a group of 36 children with expressive language delays from initial identification (20-34 months) to 7 years of age, they suggested

that one of the best predictors of outcome was gross motor skills. Results from the current study certainly suggest that children with persistent SLI are likely to have poor motor skills.

Of the 23 participants with SLI who formed the Poor Speech Group, 18 (78%) presented with motor deficits. There is thus a high co-occurrence between motor deficits and speech performance. These findings may provide some support to Flipsen's (2002) hypothesis that the slower articulation rate noted in children with residual speech errors could be related to relative speech-motor deficits.

7.2.3 Summary of Neuromotor Findings

The above results thus support the hypothesis of this study that motor difficulties are a common feature of children with persistent SLI, possibly contributing to the speech difficulties noted in this study. These results also support Hill's (2001) findings that the majority of children with SLI have significant motor difficulties in certain areas, and that motor difficulties are the rule, rather than the exception in SLI. Results from the OME confirmed significant differences between the SLI and TD groups with regard to speech motor functioning. There is thus strong support for the hypothesis that adolescents with persistent SLI present with subtle neuromotor deficits which could impact on speech production.

Motor coordination deficits affecting overall gross and fine motor coordination are influenced by the same neural substrates as speech coordination, as the motor system for speech is part of the motor system in general (Duffy, 1995). Therefore it is to be expected that a group of children with a high occurrence of motor deficits (Hill, 2001), also have a high incidence of difficulties with speech coordination, as was found in the current study.

7.3 SAB and OME Ratings as an Index to Rule in/ Rule out SLI

Reporting group trends regarding performance of SLI and TD participants on the SAB provides useful descriptive information, and adds to our understanding of SLI. However, mean scores and group trends do not indicate whether the SAB has clinical and research utility as a tool to identify SLI.

Therefore likelihood (LH) ratio analyses (also known as odds ratios) were conducted for the OME ratings, SAB Accuracy scores and SAB Number of Deviant Behaviours scores. Particularly the Number of Deviant Behaviours scores were useful in ruling SLI in or out, and the SAB scores appeared to be as useful as nonword repetition scores at identifying SLI.

In the section below likelihood ratio results will be presented for the OME, the SAB and the Children's Test of Nonword Repetition. LH ratios of greater than 1 indicate that scores or ratings in that range are more likely to come from participants with SLI; while ratios of less than 1 indicate that scores or ratings in that interval are more likely to come from TD participants. LH ratios above 10 and below 0.1 are regarded as conclusive to rule in or rule out the presence of a disorder (Sackett, 2000).

Table 7-16 reflects the LH ratios for the OME ratings, using 1*SD* and 2*SD* from the mean of the TD group as standards. Only Speech Function ratings with a cut-off of -2*SD* have high sensitivity to the presence of SLI, with moderate LH ratios at that level. Thus while SLI participants are more likely to have poor Speech Function ratings, it is not an accurate diagnostic marker on its own, but may assist in the diagnosis of SLI.

Table 7-16: Likelihood (LH) ratio analysis for OME ratings, based on SLI versus TD status.

OME sub-area	SLI		TD		LH Ratio
	No.	Proportion	No.	Proportion	
Within 1*SD* of mean of TD group (or better)					
Structure	19	0.613	24	0.774	0.79
Function	10	0.323	23	0.742	0.44
Speech Function	21	0.677	25	0.807	0.84
More than 1*SD* worse than mean of TD group					
Structure	12	0.387	7	0.226	1.71
Function	21	0.677	8	0.258	2.62
Speech Function	10	0.323	6	0.194	1.67
More than 2*SD* worse than mean of TD group					
Structure	3	0.09	2	0.065	1.39
Function	11	0.355	3	0.09	3.94
Speech Function	7	0.226	1	0.032	7.06

***Key**: LH ratios below 1 indicate a decreased likelihood of SLI, while LH ratios above 1 indicate an increased likelihood of SLI. Moderate and large increases/decreases in the likelihood are regarded as significant.*

In Table 7-17, the LH ratios for Accuracy scores on the SAB are reflected. MWL and PR scores have a moderate likelihood of ruling out SLI. At a cut-off of 1*SD*, none of the SAB Accuracy scores could predict more than a small increase in the likelihood of SLI. At a cut-off of 2*SD*, all the SAB tasks, with the exception of the Tongue Twister task, could predict a moderate increase in the likelihood of SLI, which means that a score in this range was six times more likely to be that of a participant with SLI.

Table 7-17: Likelihood (LH) ratio analysis for Accuracy scores on the Speech Assessment Battery, based on SLI versus TD status.

Scores		SLI		TD		LH Ratio
		No.	Prop.	No.	Prop.	
Less than 1*SD* worse than mean of TD group	MWL	5	0.161	25	0.807	0.2
	NWR	10	0.323	26	0.839	0.39
	PR	4	0.129	24	0.774	0.17
	SR	14	0.452	26	0.839	0.54
	TT	18	0.581	28	0.903	0.64
More than 1*SD* worse than mean of TD group	MWL	26	0.838	6	0.194	4.32
	NWR	21	0.677	5	0.161	4.21
	PR	27	0.871	7	0.226	3.85
	SR	17	0.548	5	0.161	3.40
	TT	13	0.419	3	0.097	4.32
More than 2*SD* worse than mean of TD group	MWL	20	0.645	0	0	6.45
	NWR	14	0.452	2	0.065	6.95
	PR	20	0.645	3	0.097	6.65
	SR	6	0.194	1	0.03	6.47
	TT	3	0.097	2	0.065	1.49

***Key**: LH ratios below 1 indicate a decreased likelihood of SLI, while LH ratios above 1 indicate an increased likelihood of SLI. Moderate and large increases/decreases in the likelihood are regarded as significant.*

In Table 7-18, the LH ratios for the Number of Deviant Behaviours obtained on each subtest of the SAB are reflected. The Number of Deviant Behaviours score on the Tongue Twister task appears to provide the strongest basis on which to rule in or rule out SLI, indicating a moderate decreased likelihood of SLI with scores within 1*SD* of the TD mean, and a moderate or strong/conclusive increased likelihood of SLI at 1*SD* and 2*SD* worse than the TD mean respectively. The SR Number of Deviant Behaviours score provided minimal to small likelihood ratios at all levels. Thus, while the SR subtest

indicated statistical differences between SLI and TD groups, these differences do not appear to be clinically significant.

In view of previous findings regarding the utility of using nonword repetition to identify SLI (D.V.M. Bishop, S.J. Bishop, Bright, James, Delaney & Tallal, 1999; Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth & Jones, 2000), it was decided to calculate the likelihood ratios for nonword repetition for this population (see Table 7-19).

Table 7-18: Likelihood (LH) ratio analysis for Number of Deviant Behaviours on the Speech Assessment Battery, based on SLI versus TD status.

		SLI		TD		LH Ratio
		No.	Prop.	No.	Prop.	
Less than 1*SD* worse than mean of TD group	MWL	9	0.290	28	0.903	0.321
	NWR	7	0.226	24	0.774	0.292
	PR	9	0.290	24	0.774	0.375
	SR	19	0.613	25	0.807	0.76
	TT	5	0.161	27	0.871	0.19
More than 1*SD* worse than mean of TD group	MWL	22	0.71	3	0.097	7.32
	NWR	24	0.774	7	0.226	3.425
	PR	22	0.71	7	0.226	3.142
	SR	12	0.387	6	0.194	1.995
	TT	26	0.839	4	0.129	6.504
More than 2*SD* worse than mean of TD group	MWL	14	0.452	3	0.097	4.66
	NWR	15	0.484	1	0.03	16.13
	PR	10	0.323	1	0.03	10.77
	SR	6	0.194	2	0.065	2.985
	TT	23	0.742	2	0.065	11.42

***Key**: LH ratios below 1 indicate a decreased likelihood of SLI, while LH ratios above 1 indicate an increased likelihood of SLI. Moderate and large increases/decreases in the likelihood are regarded as significant.*

Table 7-19: Likelihood (LH) ratio analysis for nonword repetition raw scores, based on SLI versus TD status.

	SLI		TD		LH Ratio
	No.	Prop.	No.	Prop.	
Less than 1*SD* worse than mean of TD group	9	0.29	28	0.90	0.32
More than 1*SD* worse than mean of TD group	22	0.71	3	0.097	7.32
More than 2*SD* worse than mean of TD group	20	0.65	1	0.03	21.67

***Key**: LH ratios below 1 indicate a decreased likelihood of SLI, while LH ratios above 1 indicate an increased likelihood of SLI. Moderate and large increases/decreases in the likelihood are regarded as significant.*

Nonword repetition scores in this group of adolescents with SLI had a small likelihood of being able to rule out the disorder in TD participants, and a large likelihood of ruling SLI in for affected individuals. These results are much higher than those reported by Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth and Jones (2000). There is a much stronger likelihood that the nonword repetition task could differentiate between children with and without SLI in the current study than in the Ellis Weismer et al study. In comparing likelihood ratios for the SAB and the nonword repetition task, it appears that Number of Deviant Behaviours on a number of the subtests of the SAB and nonword repetition both had a large likelihood of ruling in or ruling out SLI in this group when using -2*SD* as a cut-off.

Summary of LH Ratios

Since there was much heterogeneity in performance of both TD and SLI participants, with some overlap in scores between the two groups, the SAB cannot be used in isolation to identify the presence/absence of a language disorder. However, with high likelihood ratios at some levels the SAB could provide a useful index to *assist* in ruling in or ruling out language impairment, particularly SLI. In particular, the following components of the SAB appear useful to rule in or rule out SLI:

- SLI has a moderate likelihood of being *ruled* out by MWL and PR Accuracy scores, and TT Number of Deviant Behaviours scores within 1*SD* of the TD mean.
- SLI has a moderate likelihood of being *ruled in* by Speech Function ratings, MWL, NWR and PR Accuracy scores 2*SD* worse than the TD mean.
- NWR, PR and TT Number of Deviant Behaviours scores that are 2*SD* worse than the TD mean appear to provide conclusive evidence for the presence of SLI.
- Number of Deviant Behaviours scores on subtests of the SAB and the nonword repetition task both yielded a large likelihood of ruling in SLI.

The SAB clearly has utility in assisting to identify language impaired adolescents. In line with the aims of this study, the likelihood ratio analysis has confirmed the clinical significance of the results obtained on the SAB.

7.4 Risk Factors and Performance on the SAB

The SLI group differed from the TD group on a number of risk factors. The SLI group had a higher incidence of past and current phonological disorders, family history of language and learning disorders, Attention Deficit (Hyperactivity) Disorder, and significant early history. The two groups did not differ with regard to family history of speech disorders or history of Otitis Media with Effusion. Overall, the Poor Speech Group (described in 7.2.2) did not appear to differ from the SLI group as a whole with regard to risk factors.

Information regarding risk factors was obtained from the caregiver questionnaire, as well as school files. As a result of the age group targeted in this study, some informants found it difficult to recall information about preschool development. When considering the information presented below, variables rated as positive (the participant did present with this factor) were confirmed by caregiver report and/or written records. Where a variable is rated as negative, the participant reportedly did not present with this factor, although this does not exclude the possibility that the informant's recall was faulty; or no information was available. As a result, the rate of occurrence of the different variables is probably underreported in this sample.

Risk factors were considered primarily in relation to the Poor Speech Group, as one of the aims of the study was to determine if adolescents with SLI and poor speech production abilities present with a unique profile of risk factors. The risk factor variables will be discussed in the following order: History of phonological disorder, family history of language or learning disorders, family history of speech disorders, Attention Deficit (Hyperactivity) Disorder, otitis media, and significant early history.[41] Throughout the discussion in the following section, it should be considered that the sample size was relatively small, thus results should be viewed with caution.

[41] Appendix I indicates how these variables were identified.

7.4.1 History of Phonological Disorder

Many more participants with SLI (38.7%) reported a history of sound substitutions lasting beyond the age when errors could be regarded as age appropriate; compared to TD participants (9.7%). Seven (22.6%) participants with SLI reported continued speech difficulties at the time of the study, ranging from "mumbling", to "slurring", to difficulty with long words. Five (16.1%) TD participants reported current speech difficulties, in that they struggled to produce long words. One TD participant and one participant with SLI reported having a tongue thrust, although the Oral Motor Evaluation indicated that three participants in each group presented with a tongue thrust.

The number of participants in each group with a history of phonological disorder is presented in Table 7-20 below. The table compares the SLI and TD groups, as well as the SLI Poor Speech Group. The table also indicates whether phonological disorders were only present in the past (most likely during the preschool years), or whether caregivers still detected speech errors in the participants' speech at the time of the study. These results support the hypothesis that children with persistent SLI are likely to have a history of phonological disorder or to have current speech difficulties.

Table 7-20: History of phonological disorder: Comparison of SLI, Poor Speech Group and TD participants.

	Positive History of Phonological Disorder				No Reported History of Phonological Disorder	No Information
	Past	Current	Past and Current	Total		
SLI (n=31)	8 (26%)	2 (6.5%)	8 (26%)	18 (58%)	9 (29%)	4 (13%)
SLI Poor Speech Group (n=23)	5 (22%)	2 (9%)	6 (26%)	13 (57%)	7 (30%)	3 (13%)
TD (n=31)	4 (13%)	3 (10%)	1 (3%)	8 (26%)	23 (74%)	0

The percentage of SLI participants reporting a history of phonological disorders is somewhat higher than the 25% of kindergarten children with SLI and phonological disorders reported by Tomblin (1989). The fact that the participants in the current study were much older than Tomblin's group, and may reflect a more persistent type of SLI, could account for this difference.

The majority of the SLI participants with a positive history (72%) formed part of the Poor Speech Group. These results are in agreement with findings by Lewis and Freebairn (1992) that phonological disorders present in the preschool years persist in a subtle form into adolescence.

For both the SLI and TD groups, phonological disorders described in their past appeared to consist of Articulation Disorders and Delayed Phonological Disorders (Dodd, 1995b), although this classification is based primarily on caregiver report, and thus may not be accurate. Because of the high co-occurrence of speech and language disorders in the preschool population it was to be expected that fewer TD participants would report phonological disorders.

A third (n=10) of the SLI participants currently have speech difficulties (residual errors) which are noticeable to their caregivers. Their speech difficulties are therefore not only evident on contrived test stimuli such as the SAB, but are apparent during everyday communication with caregivers. Current speech difficulties for both groups of participants were described as: Difficulty with long words; "slurred" speech, "mumbling"; "mispronounces" some words. Only one participant (S20), who presented with a r→w substitution in the early school years, was still reported to use this error inconsistently. All these participants appear to fit the description of Residual Errors (RE) within the Speech Disorders Classification System (SDCS; Shriberg, Austin, Lewis, McSweeney & Wilson, 1997). Only two SLI and three TD participants who had no past reported phonological disorder, were reported to have speech problems at the time of the study, which places them in the RE-B group according to Shriberg and colleagues. It is possible that their caregivers did not recall or recognize their earlier phonological disorders. Alternatively, their current difficulties may be unrelated to past history of phonological disorders.

Summary: More than half of SLI participants had some history of phonological disorder, and there were no marked differences between the SLI group as a whole and the SLI Poor Speech Group. Caregivers reported that a third of the SLI group still had some speech difficulties at the time of the study, supporting the hypothesis that continued poor speech production is a prominent

characteristic of children with persisting SLI. There thus appears to be some overlap between the SLI population and the Residual Errors group described by Shriberg et al (1997). These results also confirm findings by Lewis and Freebairn (1992), regarding the persistent nature of phonological disorders. Results support the hypothesis that history of phonological disorder is one of the common features of the persistent SLI group.

7.4.2 Family History of Language or Learning Disorders

Of the participants with SLI, 16.1% reported a family history of AD(H)D, while 45.2% reported a family history of language and/or learning difficulties. In contrast, only 19.4% of TD participants reported having relatives with language or learning difficulties. None reported relatives with AD(H)D. These results were not unexpected, as children with SLI are known to have a higher incidence of relatives with language, learning or attention deficits (Tomblin, Freese, & Records, 1992; Tomblin, Smith & Zhang, 1997; Rice, Haney & Wexler, 1998). Information regarding parents, siblings or other family members with a history of learning or language disorders, including AD(H)D, is summarised in Table 7-21.

Table 7-21: Family history of language or learning disorders: Comparison of SLI, Poor Speech Group and TD participants.

	Positive Family History of Language/Learning Disorders		No Reported Family History of Language/Learning Disorders	No Information
SLI (n=31)	18 (58%)	Father: 4 (13%) Mother: 5 (16%) Brother: 3 (10%) Sister: 4 (13%) Grandparent: 2 (6.5%) Uncle: 2 (6.5%) Aunt: 2 (6.5%) Cousin: 4 (13%)	5 (16%)	8 (26%)
SLI Poor Speech Group (n=23)	13 (57%)		4 (17%)	6 (26%)
TD (n=31)	6 (19%)		9 (29%)	16 (52%)

These results support the hypothesis that persistent SLI is often related to genetic factors, and that the speech disorders evident in this group may, in part, have a genetic basis.

More than half of SLI participants had a positive family history of language or learning disorders, three times the number of TD participants with a positive family history. This result was expected. As was discussed in earlier chapters, a large number of studies have found a familial basis for SLI (Lahey & Edwards, 1995; Tallal, Ross & Curtiss, 1989; Tomblin, Smith & Zhang, 1997). The results found in this study are similar to that reported by Lahey and Edwards (1995) who reported that 60% of their sample had a positive family history of speech-language-learning problems; and identical to that reported by Rice, Haney and Wexler (1998), who reported positive speech/language disorder histories in 58% of SLI participants, and 19% of control participants. Results were somewhat lower than the 77% reported by Tallal, Ross and Curtiss (1989), but higher than the 46% reported by Bishop and Edmunson (1986, in Spitz, Tallal, Flax & Benasich, 1997) or the 51% reported by Tomblin (1989). These latter differences could be attributed to differences in definitions of impairment, as well as age differences in participants.

With the exception of one participant, all participants who reported affected members of their extended family, also had an affected member of the nuclear family. These results were similar to that of Rice et al (1996, in Spitz et al, 1997), who found that nuclear families of probands were more likely to experience speech and language problems than extended families.

When comparing gender ratios (mothers versus fathers and sisters versus brothers), no gender bias is apparent. This result is similar to that reported by van der Lely and Stollwerck (1996), but differs from results reported by Tomblin (1989) and Bishop, North and Donlan (1995). Rice, Haney and Wexler (1998) found differences between fathers (29%) versus mothers (7%), but no difference between brothers and sisters. Differences between the current study and previous studies could be attributed to age differences in participant groups, as the current study involved an older group of children than any of the other studies. Persistent SLI, as investigated in the current study, may represent a different

subgroup of children, with different etiological factors than the groups reported in other studies. Both the van der Lely and Stollwerck and the Rice et al studies investigated children with grammatical deficits, with notable expressive morphosyntactic impairments. The participants in the current study also had a high incidence of expressive syntax deficits, and may thus be similar to the subgroups of SLI investigated in the above two studies.

Thirteen of the participants with a positive family history formed part of the Poor Speech Group. Most of the SLI participants with a positive family history of language or learning disorders (72%) thus presented with a very poor performance on the SAB. In contrast, four of the six TD participants with a positive history of language or learning disorders, did not present with severe speech errors, as they were within one standard deviation of the mean number of speech errors for their group.

Summary: As was expected, many SLI participants had a family history of language and/or learning difficulties. SLI participants with a family history of language or learning disorders were likely to present with severe difficulties on the SAB, while the same was not true of TD participants with positive histories. Results support the hypothesis that, for a large proportion of participants with SLI, speech difficulties are part of the inherited phenotype.

7.4.3 Family History of Speech Disorders

Of the participants with SLI, 16.1% reported a definite family history of phonological or other speech disorders, compared to 25.8% of TD participants.

Table 7-22: Family history of speech disorders: Comparison of SLI, Poor Speech Group and TD participants.

	Family History of Speech Disorders	No Reported Family History of Speech Disorders	No Information
SLI (n=31)	6 (19%)	17 (55%)	8 (26%)
SLI Poor Speech Group (n=23)	6 (26%)	11 (48%)	6 (26%)
TD (n=31)	6 (19%)	10 (32%)	15 (48%)

Eight caregivers of participants with SLI did not complete this section, which may explain the difference between the two groups. SLI participants reported relatives presenting with stuttering (n=2) and phonological disorders (n=3). TD participants also reported stuttering (n=1) and phonological disorders (n=7). All these relatives had received Speech-Language Therapy to address the speech disorders.

As can be seen in Table 7-22, few participants in either group had a reported family history of speech disorders. The rate reported for SLI participants is similar to that reported by Rice, Haney and Wexler (1998) in their study of children with an extended optional infinitive (EOI) stage, where 15% of probands' families reported a history of speech or language difficulties. However, in their study, only 6% of control family members reported such difficulties, which differs markedly from the results of the current study.

Results of this study therefore support the hypothesis that a family history of speech disorders may not be a common feature of children with SLI, which is in agreement with results reported by Lewis and Freebairn (1992). Lewis and Freebairn found that the children with phonological disorder did not also have language disorders. They hypothesized that the subgroup of familial phonological disorders could be distinct from familial language disorders. However, it is also possible that caregivers underreported the incidence of family members with speech difficulties. It has been noted in previous studies that family history questionnaires may underestimate the number of family members classified as affected (Plante et al, 1996, in Benasich & Spitz, 1999). Only three of the relatives could be regarded as having phonological disorder. It is noteworthy that these relatives were parents and a sibling. As many phonological disorders would have been resolved by adolescence (or at least give the appearance of having resolved), informants may not have been aware that adult members of their families may have had phonological disorders as children. Rice, Haney and Wexler (1998) have pointed out that phonological disorder is one of the phenotypes which is detectable in young children, but tends to disappear with age, making it difficult to obtain retrospective information. In a retrospective study one is also reliant on the recall of informants, which may not

always be accurate. Thus the low incidence of positive family histories for speech disorders may have been due to methodological issues, rather than being an accurate reflection of the true incidence of familial speech disorders.

All six the SLI participants with a family history of speech disorders formed part of the Poor Speech Group, while this only applied to one TD participant. It appears that if a child with SLI has a relative with a speech disorder, he/she is likely to have poor speech, even in adolescence. If a TD participant has a positive family history, there is a much smaller likelihood that he/she will present with poor speech abilities. However, only a small proportion of children in the Poor Speech Group (26%), have a family history of speech disorder. These findings are similar to that of Fox, Dodd & Howard, (2002), who found that 28% of children with a speech disorder had a positive family history.

Summary: The results of this study indicate that the Poor Speech group is not more likely to have a family history of speech disorders than other participants, but when such a history is present in SLI participants, speech abilities are poor.

7.4.4 Attention Deficit (Hyperactivity) Disorder (AD[H]D)

Participants with SLI were six times more likely to have a positive history of AD(H)D (Table 7-23) than their TD peers, with more than half of the SLI group being diagnosed with AD(H)D, which is consistent with previous reports in the literature (Leonard, 1998). Of the participants with SLI, 58.1% were diagnosed as having AD(H)D by a medical practitioner.

Table 7-23: Attention Deficit (Hyperactivity) Disorder: Comparison of SLI, Poor Speech Group and TD participants.

	Diagnosed AD(H)D	No Reported AD(H)D	No Information
SLI (n=31)	18 (58%)	13 (42%)	0
SLI Poor Speech Group (n=23)	13 (57%)	10 (44%)	0
TD (n=31)	3 (10%)	28 (90%)	0

The Poor Speech Group mirrors the incidence of AD(H)D in the larger SLI group, suggesting that an attention deficit is not a key feature of the Poor

Speech Group, although it appears to be a common feature of participants with persistent SLI.

Results of this study thus support the hypothesis that children with persistent SLI may present with subtle neurological deficits, such as AD(H)D.

Ritalin was prescribed for fifteen of SLI participants at some point, although two participants have subsequently stopped taking all medication. One participant was using natural remedies for the ADD. Only 9.7% TD participants reported being diagnosed with AD(H)D. Of these, one TD participant was taking Ritalin, while a second participant was using homeopathic medication for ADD.

The findings reported above are in agreement with previous studies (Kovac, Garabedian, Du Souich and Palmour, 2001; Redmond & Rice, 1998), which have reported an approximate co-occurrence between SLI and AD(H)D of 50%. The high occurrence of AD(H)D in this older group of SLI participants, may lend support to Kovac et al's (2001) hypothesis that children with SLI and AD(H)D could form a more persistent subtype. What is important to note, is that in an information processing model, attention is regarded as one of the resources available for processing. Should attention be compromised, there may be a limited capacity for processing, which may impact on performance in a number of areas. This point will be discussed further in later sections.

7.4.5 Otitis Media with Effusion

As reflected in Table 7-24, there were small differences between the TD and SLI groups with regard to a history of otitis media with effusion, which is similar to findings reported by Rice, Haney and Wexler (1998). All but three of the participants with a history of otitis media with effusion formed part of the Poor Speech Group, but thirteen participants with no history of otitis media also formed part of this group. These results appear to suggest that there is not a clear causal relationship between a history of otitis media and poor speech abilities, which is in accordance with previous studies in the area (Shriberg, Flipsen, Thielke et al, 2000). The incidence of otitis media in the Poor Speech Group mirrors that of the SLI group as a whole. These findings support the hypothesis that history of otitis media is not a defining feature of the Poor Speech Group or persistent SLI, although its role as an additive risk factor cannot be excluded.

Table 7-24: Otitis media: Comparison of SLI, Poor Speech Group and TD participants.

	History of Otitis Media	No Reported History of Otitis Media	No Information
SLI (n=31)	13 (42%)	18 (58%)	0
SLI Poor Speech Group (n=23)	10 (44%)	13 (57%)	0
TD (n=31)	10 (32%)	18 (58%)	3 (10%)

Results of this study are in accordance with Shriberg, Flipsen, Thielke et al's (2000) review of 27 studies investigating the relationship between early OME and later speech delay. Shriberg et al concluded that there is currently no consensus whether children with early recurrent OME are at increased risk for speech disorder, and that no studies have indicated a direct causal association between otitis media with effusion and speech disorders. Similar to the current study, the findings of Shriberg et al's study supported a multifactorial model relating early recurrent OME to later speech disorder.

The incidence of otitis media was somewhat higher in the SLI group than was found in a study on speech disorders (Fox, Dodd & Howard, 2002), which found that 30% of their participants had a history of otitis media. However, that study sampled a much younger population (below age 7.2 years), which may explain the difference.

7.4.6 Significant Early History

Of the 31 participants with SLI, 14 presented with a significant early history, while two parents did not complete this section. Only five TD participants reported a significant early history, but eight parents did not complete this section.

Table 7-25 indicates that participants with SLI were almost three times as likely as TD participants to present with significant factors in their early history (see Appendix I for a description of these factors). Once again the figures for the Poor Speech Group mirrored those of the SLI group as a whole. As with the results regarding otitis media, there does not appear to be clear causal

relationship between a significant early history and poor speech performance. However, participants with SLI who also had poor speech abilities were more likely to have a significant early history than those with better speech abilities.

Table 7-25: Significant early history: Comparison of SLI, Poor Speech Group and TD participants.

	Significant Early History	No Reported Significant Early History	No Information
SLI (n=31)	14 (45%)	15 (48%)	2[42] (6%)
SLI Poor Speech Group (n=23)	11 (48%)	11 (48%)	1 (4%)
TD (n=31)	5 (16%)	23 (74%)	3 (10%)

The following significant factors were reported:

SLI Group	TD Group
Multiple birth (twins) (n=2)	Multiple birth (twins) (n=2)
No foetal growth after 33 weeks gestation (n=1)	Umbilical cord around neck (n=1)
Umbilical cord around neck with foetal distress (n=2)	Prolonged labour (n=1)
Small for date (n=1)	Forceps delivery (n=1)
Breech delivery (n=1)	Foetal distress (n=1)
Emergency caesarian section (n=2)	Poor sucking after birth (n=1)
Forceps delivery (n=2)	
Incubation lasting longer than one day (n=3)	
Poor sucking, with insertion of nasogastric tube (n=1)	
Defective heart valve, followed by surgery (n=1)	
Delayed motor milestones (n=4)	
Delayed speech milestones (n=7)	

The results support one of the hypotheses of this study, namely that children with persistent SLI and speech difficulties are more likely to have a history of early risk factors, which could contribute to subtle neurological dysfunction.

The results of this study are contradictory to those reported by Lahey and Edwards (1995), Tomblin, Smith and Zhang (1997), and Rice, Haney and Wexler (1998) who did not find differences between control groups and SLI

[42] These two participants were both adopted, hence their early history is not known.

groups with regard to pre- and perinatal risk factors. This difference can possibly be explained by the difference in the age groups studied. Lahey and Edwards' sample were aged 4 to 9½ years, while the participants in Tomblin et al's and Rice et al's groups were originally identified in kindergarten or preschool respectively. Age factors may result in differences between studies. For example, concordance for language impairment in twins was somewhat different in the Bishop, North and Donlan (1995) study, compared to the Tomblin and Buckwalter (1998) study. Tomblin and Buckwalter attributed these differences, in part, to age differences of the samples. Based on a review of the literature and their own findings, Tomblin et al concluded that when prenatal and perinatal events are sufficient to produce language impairment, generalized developmental deficits result, rather than specific language deficits. Subsequent follow-up studies of Tomblin's group (Catts, Fey, Tomblin & Zhang, 2002) have indicated that not all their participants continued to demonstrate language deficits at second and fourth grade level; while the long-term status of Lahey and Edwards' and Rice et al's groups are not known. The Tomblin et al study used a cutoff score of -1.25*SD* on composite language tests, while Lahey and Edwards used a cutoff of -1.3*SD* or the 10th percentile. Their groups were therefore likely to include children with mild language disorders. It is possible that children who present with persistent SLI (as in the current study) represent a more severely impaired subgroup which presents with a different constellation of risk factors than children identified as SLI in the preschool years whose language impairments a) might resolve, and b) might be of a milder nature.

The results of this study appear to be in agreement with the large epidemiological study conducted by Stanton-Chapman, Chapman, Bainbridge and Scott (2002), which concluded that biological risk factors such as very low birthweight and a low 5-minute Apgar score were associated with increased individual-level risk for SLI. The results of this study are also in accordance with the literature regarding specific learning disability, which, as discussed in earlier chapters, appears to be related to pre- and perinatal risk factors. In particular, this study appears to concur with findings of the Groningen Project (Hadders-Algra & Lindahl, 1999), which reported that two aspects of minor

neurological dysfunction, dysfunctions of manipulative ability and coordination problems, correlated closely with pre- and perinatal events. Many of the participants with SLI in this study presented with such motor deficits (see 7.2.2).

7.4.7 Summary of Risk factor Variables

The SLI and TD groups differed substantially with regard to history of phonological disorders, family history of language and/or learning difficulties, AD(H)D, and significant early history. The SLI and TD groups differed slightly in terms of history of otitis media, but showed no difference in family history of speech disorders. Results of this study point to a multifactorial etiology for persistent SLI, combining a genetic component with pre- and peri-natal risk factors. These results are in agreement with a hypothesis proposed by Bishop (1992) with regard to her twin study, that genetic factors are an important etiological factor in language difficulties which resolve, but that more persistent language difficulties are evident when other adverse factors are experienced in addition to the genetic predisposition.

None of the risk factors investigated in this study were markedly more prevalent in the Poor Speech Group than in the persistent SLI group as a whole. Thus the current study could not identify risk factors which uniquely contribute to poor speech in adolescents with SLI. However, the small sample size, and the fact that the two groups (Poor Speech versus SLI as a whole) differed markedly in size, may have contributed to this finding. The contribution of potential risk factors to speech difficulties in SLI requires further investigation.

7.5 Summary of Results

The Speech Assessment Battery (SAB) yielded significantly different results for the SLI and TD groups. The SLI group obtained significantly poorer Accuracy, Deviation and Number of Deviant Behaviours scores for all subtests, as well as a slower rate of speech on the Tongue Twister task. It was evident that the SLI group found these tasks extremely challenging and that they expended much effort in their attempts to produce accurate responses. Results on the SAB showed some correlation with expressive syntax abilities, a characteristic area of

deficit in SLI, suggesting a link between speech output abilities and expressive syntax even in an adolescent population.

After analyzing the deviant speech behaviours, it was evident that the SLI group largely produced similar deviant behaviours as the TD group, but that these behaviours were just more frequent in the SLI group. One notable exception was the fact that SLI participants were more likely to produce assimilatory errors resulting in nonwords, suggesting inefficient postlexical editors in this group. Furthermore, the SLI group was more likely to omit phonemes than the TD group, which is thought to relate to poor motor speech abilities in this group. SLI participants were also more likely to produce additions, probably indicating a poor specification of syllable frames.

On the Oral Motor Evaluation (OME), SLI participants obtained poorer Function and Speech Function ratings than TD participants. SLI participants also more frequently reported a history of motor difficulties. It is thus apparent that the SLI group presented with oral motor deficits which could impact on speech production.

The SAB Number of Deviant Behaviours scores for the Nonsense Word Repetition, Phrase Repetition and Tongue Twister tasks yielded a large likelihood of being able to rule in SLI when used as a diagnostic tool. It would appear that the SAB has as much clinical utility as the nonword repetition task to identify language impairment.

The following risk factors were identified in this group of participants with persistent SLI: history of phonological disorder, family history of language or learning disorders, AD(H)D, and significant early history. There were no marked differences between the SLI group as a whole and the Poor Speech Group. Unlike previous risk factor studies, not only genetic risk factors were implicated, supporting the hypothesis that individuals with persistent SLI may present with a larger number of risk factors.

In the following chapter, the results described in this chapter will be discussed further and theoretical and clinical implications of this study will be considered.

8 General Discussion and Conclusion

"When we deal with speech, we deal with the essence of man. Only human beings have mastered speech. It is what sets us apart from all other species." (Van Riper & Emerick, 1984, p.29).

Speech provides us with a window to the whole communication process, particularly in children who have not mastered written language. Speech is the final stage in the language processing chain. Thus careful analysis of speech may give us insights into other aspects of the communication process, such as language and memory. At the same time, speech output allows an individual to demonstrate his or her mastery of language and memory processing. This study set out to put the speech back into speech therapy. Results from the study indicate strongly that speech production is impaired in adolescents with SLI, suggesting that it is shortsighted to ignore speech output in this population. Instead, the speech deficits seen in persistent SLI may have far-reaching implications for processing in the areas of language and memory for these adolescents.

Results presented in the preceding chapter provide clear and compelling evidence that adolescents with SLI present with impaired speech processing in terms of phonological output. Differences between the SLI and TD groups were not only significant statistically, but also clinically. The clinical observation of speech deficits in adolescents with SLI, which led to this research study, was thus validated empirically.

Results provide support for a functional capacity view of SLI, in that participants could perform simple speech tasks but broke down as task demands increased. Consequently, speech as a resource in the language processing chain is compromised. In accordance with the threshold hypothesis discussed in Chapter 3, these speech deficits are likely to interact with other deficits in vocabulary, morphosyntax, memory and attention to affect performance on any task requiring verbal output.

The findings reported in Chapter 7 support the main hypotheses of this study, namely:

1) Speech deficits occur with sufficient frequency in adolescents with persistent SLI to be regarded as a common characteristic of this population.
2) Speech deficits in the SLI population do not necessarily resolve, but may persist into adolescence as subtle, context-dependent inconsistent errors, evident particularly on tasks involving motorically and phonologically complex stimuli.
3) Speech production appears to be more resource-demanding for adolescents with SLI than typically developing peers.
4) Speech deficits do not occur in isolation, but interact with language processing and memory, particularly expressive syntax, which is a characteristic area of deficit in the SLI population.
5) Speech deficits seem related, in part, to neuromotor deficits affecting oral motor coordination and planning.
6) Persistent SLI is associated not only with genetic factors, but also with pre- and perinatal risk factors, to a greater extent than previously reported in the SLI population, suggesting that persistent SLI as a subtype may be associated with different risk factors or combinations of risk factors than the general SLI population. These risk factors may go some way to explaining the neuromotor deficits that were so common in this population.
7) Persistent SLI is frequently associated with AD(H)D, suggesting that attention as a resource for language and speech processing is compromised in adolescents with persistent SLI.

In accordance with results obtained in this study, the nature of persistent SLI in adolescents is summarized in Figure 8-1.

The clinical presentation of persistent SLI includes not only linguistic and memory deficits, as has been well-described in the literature, but also oral motor and speech deficits. Risk factors for the persistent SLI group included not only the genetic factors identified in previous studies, but also factors related to early history. Furthermore, a large number of the persistent SLI group (58%) presented with AD(H)D, suggesting that attention is often compromised in this population, thus adding to their processing difficulties.

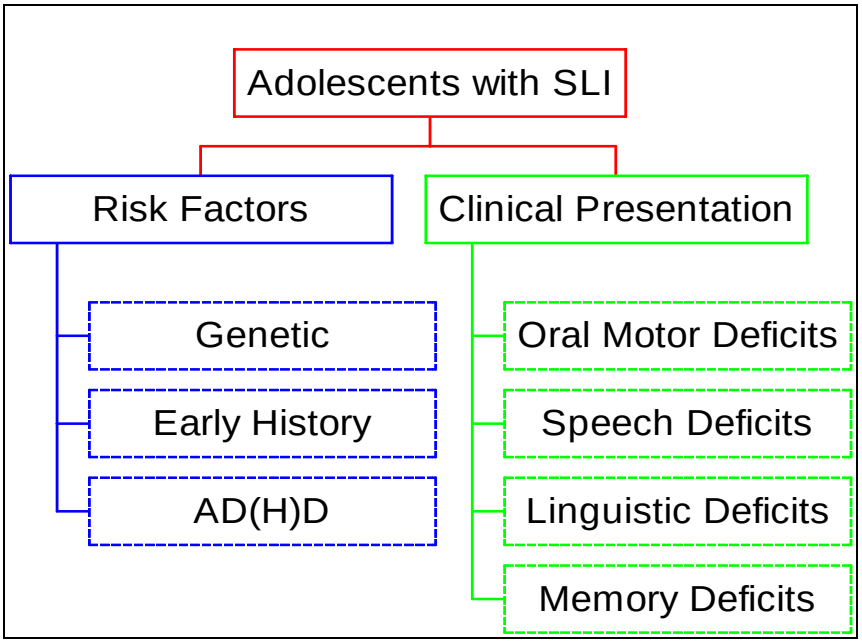


Figure 8-1: The nature of SLI in adolescence.

The findings of this study will be discussed in the following order. Firstly, explanations for speech errors in adolescents with SLI will be presented, followed by a discussion of the implications of such speech deficits. Contributions of this study towards the search for a phenotype for SLI, as well as evidence for a multifactorial etiology for SLI will be presented. The primary instrument used in this study, the Speech Assessment Battery (SAB) will be evaluated, prior to a discussion of the clinical and research implications of the current study.

8.1 Explanations for Poor Speech Abilities in Adolescents with SLI

The results presented in the preceding chapter clearly indicate that adolescents with SLI have poorer speech abilities than their typically developing peers. Possible explanations for these speech deficits will be explored in the section below within a resource allocation framework and a functional capacity viewpoint of SLI.

8.1.1 Motoric Factors

There is compelling evidence that adolescents with SLI frequently present with motoric deficits. Nearly three quarters (74%) of the participants with

persistent SLI were reported to have motor coordination deficits, while the SLI group performed significantly worse than the TD group on measures of oral motor Function and Speech Function. Results from the OME indicated that participants did not necessarily have difficulties in producing single movements, but that difficulties were evident when producing movements requiring high levels of control (such as slow circumoral tongue movements) or rapid sequencing and repetition of movements (such as repetitions of "buttercup" or alternating /u/ and /i/), which concurs with previous studies regarding motor function in SLI (e.g. Stark & Tallal, 1981b; Rutter, Mawhood & Howlin, 1992; Hill, 2001).

While the finding that adolescents with SLI have motor deficits is not a new one (cf Bishop, 2002b), the current study provides evidence that these motor deficits affect oral motor skills, and that, at least in the case of persistent SLI, these deficits do not resolve before adolescence.

These findings suggest, firstly, that a simple screening of oral structure and function, as is customary in SLI research[43], is unlikely to detect these subtle motoric deficits which are only evident on demanding tasks.

Secondly, it appears that the motoric component of the speech processing chain is frequently compromised in this population. Adolescents with SLI are (usually) not incapable of producing specific speech sounds or multisyllabic words, but it is likely that correct production of sustained speech output, particularly when task demands increase, require the allocation of additional resources. The hesitations, repetitions and revisions produced in such high numbers by participants with SLI may indicate that additional monitoring and correction of motoric output is required. As will be discussed in 8.1.4, this has implications for the automaticity of speech production, which places greater demands on resource allocation. Specifically, the slower speech rate resulting from these disfluencies places higher demands on the buffer component of speech production (as discussed in Chapter 2) (Field, 2004). The planned phonological structure of the intended utterance has to be stored in the buffer for a longer period, rendering it more vulnerable to decay (Gathercole & Baddeley, 1994), while also requiring the allocation of more resources to the buffer.

[43] See, for example, Bishop, 1992; Aram, Morris & Hall, 1993; Leonard, Eyer, Bedore & Grela, 1997; Leonard, 1998; Kaderavek & Sulzby, 2000; and Montgomery, 2000.

Thirdly, the motoric deficits evident in persistent SLI provide further evidence of subtle neurological impairment. As Rice (2004) pointed out, the linguistic and processing deficits common to SLI reflect impairment in neurocognitive pathways. It appears that these neurological deficits affect more than just language and processing and also affect motoric control. These neuromotor deficits are likely to underlie at least some of the speech difficulties observed in this study. Such deficits compromise the phonetic stage of speech production (van der Merwe, 1997; Caruso & Strand, 1999; Field, 2004) and affect the actual articulation of speech sounds. In terms of neuromotor development, these findings may suggest that neurological development is even more protracted in adolescents with SLI than in typically developing adolescents (e.g. Brown & Minns, 1999; Paus et al, 1999).

Fourthly, the motoric deficits evident in the participants with SLI are likely to reduce their operating range for speech, which may not affect speech directly, but may make speech gestures more difficult to produce (Robin, Solomon, Moon & Folkins, 1997). Consequently, this population may lack the flexibility to manage variability during development or movements outside the operating range, such as the production of longer stimuli or unfamiliar stimuli with complex phonological structure. As was discussed in 2.4.2, maximal limits of the speech production system provide an envelope, within which the operating range is the part of the envelope typically used for a given task (Robin, Solomon, Moon & Folkins, 1997). From results obtained on the OME, it appears that for adolescents with persistent SLI, this operating range is reduced compared to typically developing peers, suggesting that complex speech stimuli exceed their typical operating range sooner than is the case for typically developing adolescents. Thus, speech stimuli which are produced with ease by TD adolescents exceed the operating range for adolescents with persistent SLI, resulting in more frequent errors and the need to allocate more resources to speech output. Once again, the implication is that adolescents with SLI are able to manage simple speech tasks, and evidence breakdown in speech output only when their operating range is exceeded. Assessment of speech in this population, whether for diagnostic purposes or to determine eligibility for discharge, has to

consider operating range for speech, and find a way to measure how quickly this operating range is exceeded.

Finally, in terms of the explanations of SLI discussed in Chapter 3, it is clear that SLI is not only a language deficit, nor is it only a deficit of specific mechanisms, such as memory (as suggested by Gathercole & Baddeley, 1994 and Adams & Gathercole, 1995, 2000). The motoric deficits observed in this group of adolescents with persistent SLI provides support for the hypothesis that SLI is related to processing limitations (e.g. Leonard, 1998; Evans, 2001) related to deficits in a number of areas which interact with each other to produce a threshold effect (Gillam, Hoffman, Marler & Wynn-Dancy, 2002). This viewpoint will be discussed further in 8.2.1.

8.1.2 Lexicalisation

More than half of the errors (52%) produced by participants with SLI affected phonemes, being either syllable structure changes (additions and omissions) or phoneme substitutions, which is strongly suggestive of difficulties with the phonological stage of lexicalisation (see 2.2.1).

These adolescents with persistent SLI clearly have difficulty with speech production in terms of both voluntary and automatic activity (Garman, 1990) as discussed in Chapter 5. At a voluntary level, these adolescents have deficits of attention and working memory (see Chapter 7), apparently reducing the resources available for voluntary tasks. The participants also presented with limited linguistic knowledge, which impacts on the lexical and syntactic stages of speech production, as these stages would either be inadequate for accurate speech production, or would be resource-demanding. At an automatic level, it is clear that the motoric deficits evident in this population may affect the automaticity with which speech tasks are performed, thus affecting the phonetic stage of speech production.

Participants with SLI produced a higher proportion of syllable structure changes, which may be the result of poor specification of a syllable frame during phonological encoding (Levelt, 1992), a difficulty with motor planning during speech (van der Merwe, 1997) or a short term memory deficit, where the stimulus is recalled incorrectly. Results from the current study cannot be used to support

one or more of these hypotheses. However, in view of the heterogeneity of the SLI population, it is likely that different explanations apply to different individuals, and that all three these explanations, either singly or in combination, may apply to subtypes of SLI. Regardless of which explanation applies, it is clear that parts of the speech processing chain are compromised, lending support to the idea of a threshold effect: deficits in one or more of these areas may interact with other linguistic and memory deficits to impair verbal output.

Errors involving phoneme addition, omission or substitution were more likely to result in nonwords when produced by participants with SLI than TD participants. This is in contrast to the lexical effect discussed in 4.5.2, which is typical of speech errors (Edwards & Lahey, 1998). There are two possible explanations for this phenomenon. Firstly, adolescents with SLI may have less access to familiar underlying representations to aid storage of phonetic sequences in working memory or to form phonological representations for unfamiliar or long sequences (Edwards & Lahey, 1998). It is possible that the limited vocabulary typical of persistent SLI (e.g. Clarke & Leonard, 1996; Evans, 2001) results in a smaller store of lexical and syllable representations. Secondly, adolescents with SLI may have less efficient postlexical editors (Levelt, 1992) or monitoring mechanisms (Laver, 1980; Field, 2004) (see discussion in 2.5). This inefficiency may be related to resource allocation, for example, insufficient attention allocated to this task or inadequate storage in the buffer. Again, regardless of which explanation is correct, it is clear that aspects of speech processing related to the monitoring function are compromised, whether on a lexical, attention or memory level. Such deficits are likely to interact with the motoric and phonological deficits identified above, as well as with other linguistic and memory deficits, to contribute further to a threshold effect.

8.1.3 Monitoring Function

The types of errors produced by participants provide evidence of both prearticulation detection and correction of covert errors (Laver, 1980) (hesitations and prolongations) and postarticulation monitoring and correction of overt errors (revisions).

It was evident that for both groups of participants the phonetic context of target utterances largely influenced substitution errors, as assimilation errors were frequent. This is in accordance with previous findings reported in the literature, that contextual errors account for a large proportion of errors in nonaphasic speakers (Goldman, Schwartz & Wilshire, 2001). As was expected in citation tasks, participants were able to activate appropriate lemmas, but struggled at lexeme level, as indicated by the phonological errors (Hanley & Kay, 1997).

The phoneme substitutions produced by TD participants were more likely to result in real words, particularly in the Phrase Repetition, Sentence Repetition and Tongue Twister tasks. This finding suggests that TD participants also considered the syntactic and semantic context of the utterances when monitoring the output. It is possible that the syntactic and lexical deficits prevalent in the SLI population prevented them from performing the monitoring function effectively, thus producing results contrary to the lexical effect commonly reported in speech error literature (Levelt, 1992; Gagnon, Schwartz, Martin, Dell & Saffran, 1997). This finding suggests that the postlexical editor postulated by Levelt functions less effectively in adolescents with SLI than in their age-matched peers.

It is unlikely that a single factor can explain the inefficient monitoring evident in the SLI group. Instead, the poor monitoring is thought to be due to a threshold effect, where subtle deficits in a number of areas interact to produce deficient processing. Specifically, the poor motoric abilities discussed above require the allocation of more resources to the motoric aspect of speech production, thus reducing resources available for other aspects of language production. Furthermore, the linguistic, memory, attention and lexicalisation deficits could interact with the motoric deficits to reduce the amount of resources available for the monitoring function.

8.1.4 Automaticity

The differences among Accuracy, Deviation and Number of Deviant Behaviours scores indicate that participants with SLI did not produce complex speech stimuli rapidly and automatically. The Accuracy scores may serve to overestimate their speech ability, as their ability to produce correct responses occurs only after hesitating, repeating or self-correcting some of these items.

These results suggested that a simple right/wrong distinction (e.g. Kamhi & Catts, 1986) is not sensitive enough when scoring responses on speech tasks for an adolescent population without overtly diagnosed speech disorders and that Deviation or Number of Deviation scores may more accurately distinguish performance between groups as these scores reflect the amount of effort required or automaticity of responses.

Results therefore indicated that participants with SLI required greater effort to produce acceptable responses, suggesting that more resources have to be allocated to this task. The reduced automaticity of responses may be due to a number of factors, including motoric factors; factors related to lexicalization, such as specification of syllable frames; or a smaller store of syllables due to limited lexical knowledge. In terms of motoric factors, there is ample evidence to suggest that motor speech has a protracted development, involving reduced levels of voluntary control and increased automaticity with an increase in age (Walsh & Smith, 2002). Results from the current study suggest that in adolescents with persistent SLI this development is even more protracted and that these adolescents have even less automaticity of speech production than typically developing peers.

Whatever the reason for reduced automaticity, the fact remains that participants with SLI took longer to produce acceptable responses and frequently failed to produce a correct response. As was discussed in 4.4.2 a slower speech rate can potentially impact on working memory in general, but also specifically in terms of the buffer required for speech production (Field, 2004). Compared to typically developing peers, planned utterances have to be stored for a longer time before being articulated, rendering the output vulnerable to decay (Baddeley, 1997). More resources therefore have to be allocated to working memory, which may reduce resources available for other aspects of processing. At the same time, motoric and lexicalization deficits necessitate the allocation of more resources for the phonetic and phonological stages of speech production (see model presented in Chapter 2), with the result that fewer resources may be available for working memory. In terms of a threshold effect, there may therefore be subtle weaknesses at a number of stages of speech production, affecting automaticity, and acting as a

drain on resources, with the result that insufficient resources are available to perform the speech task accurately.

8.1.5 Conclusions Regarding Speech Errors in Persistent SLI

In Chapter 2, speech production was discussed in relation to models proposed by Dell (Dell & O'Sheaghda, 1992), Levelt (1992), van der Merwe (1997), Caruso & Strand (1999), as well as the summary model described by Field (2004) (see Figure 2-1). Figure 8-2 provides a summary of the findings regarding speech deficits in adolescents with persistent SLI with regard to Field's (2004) proposed summary model of speech production.

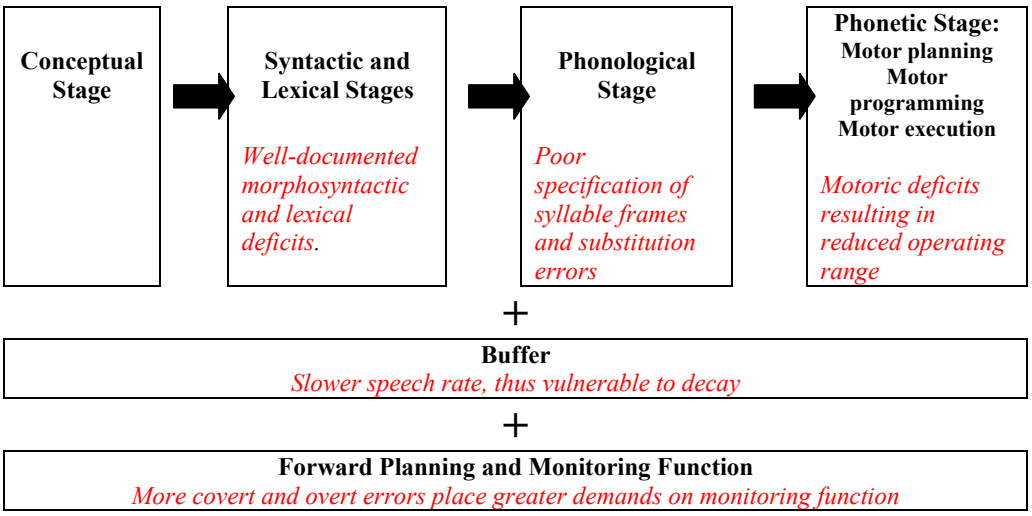


Figure 8-2: Model of speech production: Hypothesized breakdown in adolescents with SLI.

With the exception of the conceptual stage, the current study demonstrated weaknesses in every aspect of speech production, indicating that the whole speech production system is vulnerable in adolescents with SLI. Deficits were evident in terms of motoric factors, lexicalisation and the monitoring function. The high number of errors produced by the SLI group suggests that more demands are being placed on the monitoring function, while the proportionally high number of errors resulting in nonwords suggests that monitoring is not effective. At the same time, the semantic and morphosyntactic deficits that are characteristic of SLI may also affect speech production. All these deficits suggest that speech

production requires more voluntary control in this population, hence affecting automaticity, as well as reducing the operating range available for speech.

There therefore does not appear to be a single explanation for the speech deficits observed in adolescents with SLI. Instead, a number of factors appear to interact. Thus, rather than deficits in a single mechanism being used to explain these speech deficits, it is proposed that the functional capacity of the speech production system is compromised by deficits in a number of different areas: motoric, lexicalisation, linguistic (semantic and morphosyntactic), and memory. These deficits interact to overcome the redundancy of the speech production system (Caruso & Strand, 1999) (discussed in 4.2.6), which normally serve to reduce the number of overt errors produced. It appears that speech production is affected at too many levels for redundancy to operate effectively.

8.2 Implications of Speech Deficits in Adolescents with SLI

The presence of speech deficits in adolescents with SLI has implications for a number of areas. In the section below, these implications will be discussed with regard to the nature of SLI in adolescence. Explanations for SLI will be revisited in view of findings from the current study. Thereafter the correlation between speech deficits and expressive syntax will be explored, followed by a discussion of implications for diagnostic criteria for SLI.

8.2.1 Adolescents with SLI

This study set out, in part, to explore the nature of persistent SLI in adolescents. Results of the study confirmed the linguistic deficits (syntactic, semantic and discourse limitations) and memory deficits documented in previous studies, but also found compelling evidence for persistent speech deficits in this population (see Figure 8-1). These adolescents have mastered the speech sounds of English, thus superficially it appears that their speech abilities are intact. However, they clearly have a reduced operating range for speech due to motoric deficits and weaknesses at the phonological stage of speech production. When required to produce motorically or phonologically complex words, these adolescents are more likely to produce substitution or syllable structure errors, with an increase in fluency errors (hesitations, repetitions and revisions). Their

monitoring of speech output is also less efficient than that of TD peers. At the same time these adolescents have oral motor deficits evident on a detailed Oral Motor Evaluation. These deficits are particularly evident on tasks requiring rapid sequencing of oral movements or speech sounds.

The frequent comorbidity of speech and language disorders noted in preschoolers thus persists into adolescence, although the nature of the speech deficit changes. Whereas preschoolers present with errors affecting specific speech sounds or sound patterns, adolescents present with context-dependent, inconsistent errors which are dependent on task demands. Tasks which are demanding of resources result in a breakdown of speech production.

In line with findings by Bishop (2002b), results of the current study suggest that motor deficits, particularly oral motor deficits, are part of the clinical picture of SLI, and that these deficits are still apparent in adolescence. Oral motor deficits noted in younger children therefore do not resolve, but are still present in adolescence, affecting the production of complex phoneme sequences.

A further finding regarding the nature of SLI in adolescence, is the fact that attention deficits occur commonly (in 58% of participants). Clinicians and researchers working with this population thus have to be aware that attention will often be compromised in this population. Diagnostic, intervention and research tasks have to take this into consideration. At the very least there are strong indications that research studies should document whether participants presented with AD(H)D, and consider the potential impact of such attention deficits on research tasks. The impact of attention as a resource in language and speech processing has not been investigated sufficiently.

The automaticity of speech production is compromised in adolescents with persistent SLI. This population finds speech production more effortful and requires the allocation of more resources to produce acceptable speech output than TD peers. As was discussed in Chapter 4, one can expect that as the syntactic, lexical and discourse demands of linguistic tasks increase, these adolescents are more likely to experience either a breakdown in speech, or a breakdown in language output because of trade-offs with regard to resource allocation. As language demands increase during adolescence, such trade-offs may become more

common. Consequently one could wonder how much of the linguistic deficits noted in demanding language output tasks in this population (Nippold, 2004), is due solely to linguistic deficits, and how much speech deficits contribute to the apparent expressive language deficits.

The findings of this study also have implications for younger children with SLI. If these adolescents, who have completed their phonetic inventory of English speech sounds still present with speech deficits, one can expect that younger children, who are still in the process of acquiring speech sounds and who are undergoing more marked anatomical changes with regard to structures required for speech (Kent, 1999), may have even more marked speech deficits. The reduced operating range for speech evident in adolescents with SLI, would have an even greater effect on younger children, who have to deal with more variability and developmental changes.

At the same time, the findings of the study may also have implications for adults with SLI. If these adolescents with SLI, who have complete phonetic inventories and have largely completed the physical development required for speech still have such marked speech deficits compared to TD peers, it is unlikely that they will "catch up" before adulthood. It can therefore be anticipated that adults with SLI are more likely to have speech deficits (as was found by Tomblin, Freese & Records, 1992) which can impact on their communicative abilities in social or vocational settings, thus affecting the way in which they are perceived by friends, relatives and employers.

Clinicians working with adolescents with persistent SLI thus have to be aware that the nature of the disorder encompasses more than just linguistic deficits, and also includes motoric and speech deficits. As will be discussed in 8.3, adolescents with persistent SLI also appear to present with a different profile of risk factors than the general SLI population.

8.2.2 Explanations of SLI

Results of the current study could provide support for both limited resource and limited capacity views of SLI, but are felt to be most representative of the diminished functional capacity viewpoint described in 3.3.3 (Evans, 2001; Fazio, 1998; Montgomery, 2002a). Deficits are found in too many areas for a

single deficit to account for SLI. Instead these deficits are likely to interact with each other, operating in a bi-directional manner (Montgomery, 2002c) to slow linguistic processing and yield the characteristic profile of deficits seen in SLI, which, based on the current study, is now thought to include speech difficulties.

The motoric and lexicalisation deficits (evident in the high number of phoneme substitution and syllable structure errors) found in this group suggest that these participants have a limited capacity for speech, and consequently, language production. At the same time, the high incidence of AD(H)D and memory deficits in this group suggests that cognitive resources for language processing are limited.

There is certainly evidence to support a functional account for the information processing deficits found in the SLI population. Specifically with regard to speech production, these adolescents with persistent SLI were able to produce adequate speech output in undemanding contexts. They therefore apparently have the capacity to perform simple tasks. However, because of their reduced operating range for speech, an increase in task demands leads to a decrease in task performance. Such a finding reflects limited functional capacity of the speech processing system and supports the idea of a threshold effect (Gillam, Cowan & Marler, 1998). It is apparent that these adolescents with SLI had deficits in a number of areas: speech production, linguistic, memory and attention deficits. A deficit in one of these areas may not be sufficient to lead to breakdown of language processing, specifically language production (in view of this study's emphasis on speech output). However, deficits in a number of areas may have an additive effect to produce breakdown, or render the language system more susceptible to breakdown with an increase in task demands. This study proposes that, for some individuals, speech production deficits, when added to existing underlying processing and linguistic deficits, may lead to (or exacerbate) an overt expressive language impairment (see Figure 8-3 and Figure 8-4).

Further support for the hypothesis of a threshold effect emanates from the fact that, although the group of SLI participants had an increased likelihood of deficits in a number of areas, not all participants had deficits in all areas. It is therefore likely that, rather than one mechanism being responsible for all observed

errors, it was the combination of a number of different mechanisms, which may differ from participant to participant, which resulted in errors.

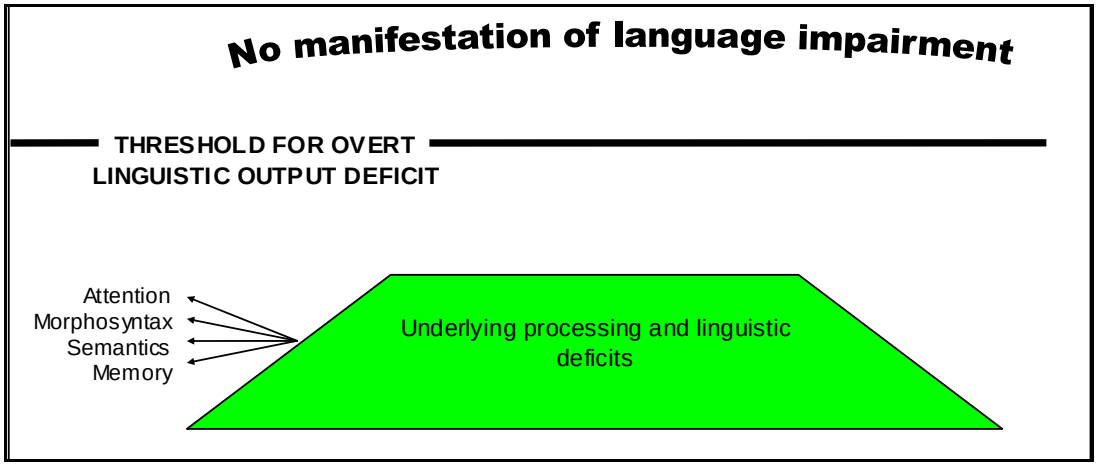


Figure 8-3: Underlying processing deficits insufficient to manifest as language impairment.

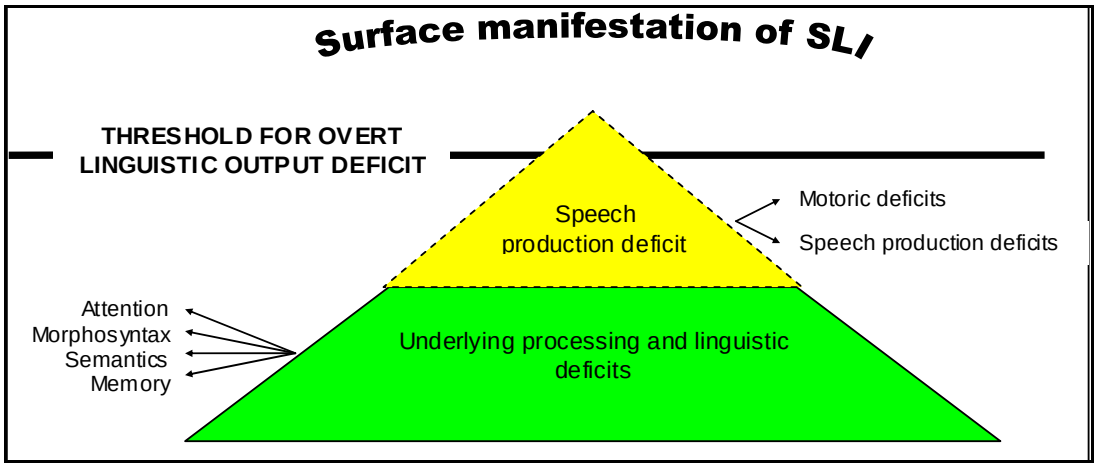


Figure 8-4: Speech production deficits leading to a threshold effect.

The study provided some preliminary evidence for a threshold effect in terms of the participants' ability to manage structural defects. None of the TD participants with structural defects produced distorted speech sounds, while several of the participants with SLI and structural defects produced inconsistent distortions. The inconsistency of these distortions indicates that the participants could produce acceptable versions of these sounds, but could not sustain adequate

production under certain circumstances. One explanation for this phenomenon is that the participants with SLI are less able to compensate for structural defects because of deficits in other areas. When faced with phonologically or motorically complex words, weaknesses in motoric functioning, lexicalization and/or monitoring may affect the individual's ability to compensate for structural defects.

The SAB was designed to minimize the influence of linguistic and memory factors on speech production. However, the clear evidence for speech deficits can lead one to make certain assumptions regarding the interaction among speech, language and memory factors previously discussed in Chapter 4. Firstly, if an increase in the motoric and phonological complexity of words can lead to a breakdown in speech production, it is likely that this breakdown will be exacerbated by an increase in linguistic complexity. There is ample evidence in the literature that increases in linguistic complexity affect speech production, including motoric aspects of speech (e.g. Enger, Hood & Shulman, 1988; Crary, 1993; Kleinow & Smith, 2000; Dromey & Benson, 2003). One can therefore conclude that when linguistic complexity is increased, for example in discourse tasks, or in tasks requiring the production of complex morphosyntactic structures, speech is more likely to break down, particularly when phonologically complex words are involved. Tasks designed to measure expressive morphology, requiring the production of both linguistically and phonologically complex words, may thus be measuring both morphology and speech output.

One also needs to consider the possibility of trade-offs (previously discussed in 3.3.3). It is widely accepted that as task demands increase, processing trade-offs occur (Johnston, 1992). Correct speech production may have high pragmatic value, since speech errors can lead to communicative breakdown. When verbal output task demands increase, an individual may therefore focus cognitive resources on maintaining correct speech output, with the result that inadequate resources are available for other aspects of language processing, such as working memory or language output. What may appear to be impaired linguistic or memory performance, may be the result of, or be exacerbated by speech deficits.

Secondly, the presence of speech deficits has implications for working memory functioning, affecting both the phonological loop and the central executive within Baddeley's model of memory. As discussed in 4.4.2, poor speech abilities impact directly on the functioning of the phonological loop. Rehearsal may be affected, where stimuli are repeated incorrectly because of a breakdown in speech production. The slower speech rate noted in this group due to hesitations, repetitions and revisions, would also affect rehearsal in the phonological loop, as stimuli would be more prone to decay (Baddeley, 1997). At the same time, under demanding conditions speech production appears to be a resource-intensive task for adolescents with persistent SLI. The central executive may therefore have fewer resources available to allocate to working memory functioning, leading to a breakdown in storage and retrieval (Baddeley, 1997), or, within the Daneman and Carpenter resource-sharing model, resources are allocated to processing, rather than storage (Goolkasian & Foos, 2002). At the same time, the more frequent hesitations and overall slower speech rate would impact on the buffer during speech production, as information has to be stored for a longer period prior to articulation (Field, 2004). Production of phonologically and motorically complex words is therefore more demanding of memory resources and may lead to inadequate storage of information.

As shown in Chapter 4, there is substantial evidence in the literature that there may be reciprocal relationships among speech, language and memory. Literature in the area of SLI has amply documented the language and memory deficits common in this population (e.g. Leonard, 1998), and much has been written regarding the implications of reciprocal interactions between these two areas (see discussion in 4.4.3). The current study has now added evidence that speech is also impaired. Based on findings from the current study, it appears that not only language and memory deficits are typical of individuals of SLI, but, at least in the persistent SLI group, speech deficits are also common. Instead of just considering a two-way interaction between memory and language, one now has to consider a three-way interaction among speech, language and memory, as was shown in Figure 4-1.

As was discussed in Chapter 4, phonological memory is often measured by nonword repetition. The high incidence of speech deficits in the persistent SLI group suggests that results from nonword repetition tasks should be interpreted with caution. Nonwords as used in the Children's Test of Nonword Repetition (Gathercole & Baddley, 1996) and the Dollaghan and Campbell (1998) instrument can be regarded as phonologically complex due to length and unfamiliarity (van der Merwe, 1997). While the impact of linguistic factors such as lexical knowledge and familiarity of syllables on nonword repetition has been studied extensively (Dollaghan & Campbell, 1998), little has been done to investigate the impact of speech factors. The high correlation between Multisyllabic Word Repetition (words which were selected for their motoric and phonological complexity) and the Children's Test of Nonword Repetition suggests that speech factors may impact on nonword repetition, but this area bears further investigation.

8.2.3 Correlation with Expressive Syntax

It is not unexpected to find strong correlations between expressive syntax and speech production. As Luria pointed out, expressive language would be impossible without the concerted working of at least the primary and secondary motor cortices (Kagan & Saling, 1988). There are some parallels between persistent SLI with speech difficulties and Luria's efferent motor aphasia, which is characterized by grammatical impairment and difficulties with skilled, sequential movements (Kagan & Saling, 1988), suggesting that functioning of the posterior third of the first left frontal gyrus may be compromised.

In view of the fact that the stimuli used in the SAB consisted of simple syntactic constructions, which are well within the capabilities of even a language impaired adolescent population (as discussed in Chapter 5), it is unlikely that expressive syntax deficits influenced speech errors. In fact, all the morphosyntactical structures used in the Phrase and Sentence Repetition and Tongue Twister tasks, should have been acquired before age six years (Crystal, 1980), suggesting that even these adolescents with persistent SLI should have mastered these constructions. Instead, it is postulated that the common underlying processes involved in producing spoken language could explain this correlation.

It is therefore likely that participants with SLI struggled with expressive syntax not only because of poor syntactic knowledge, but also because of difficulties with speech production. This correlation should be investigated further in future research studies.

8.2.4 Diagnostic Criteria for SLI

Results from this study suggest that certain diagnostic criteria for SLI need to be considered more carefully and described more rigorously in empirically-based articles. Chapter 5 highlighted the difficulties of operationalising diagnostic criteria for SLI. Apart from the lack of homogeneity inherent within the SLI population, the variation in the manner which diagnostic criteria are applied renders this population even more heterogenous.

Specifically the criteria regarding phonological status and neurological functioning need to be considered. This study has shown clearly that speech deficits are common to many individuals with persistent SLI, with 74% falling in the Poor Speech Group. Hence, excluding children with speech deficits from studies on SLI, as has been done in previous research studies (e.g. Ellis Weismer& Hesketh, 1996; Leonard, McGregor & Allen, 1992; Oetting, Rice & Swank, 1995; Leonard, Eyer, Bedore & Grela, 1997; Frazier Norbury, Bishop & Briscoe, 2002; Montgomery, 2002a) would result in a biased sample, rendering the validity of these studies questionable.

With regard to neurological functioning, this study indicated that a high number of participants with persistent SLI had motoric deficits (74%) and/or AD(H)D (58%), indicating that subtle neurological deficits are common in this population. Studies have generally excluded "frank" or "gross" neurological deficits (e.g. Gillam & Carlile, 1997; Montgomery, 2000a, 2002a) without specifying what is meant by these terms. While the current study indicates that subtle neurological deficits are common in the persistent SLI population and therefore cannot be excluded in diagnosing the disorder, the potential impact of such motoric and attentional deficits on performance of empirical tasks must be considered.

Attention is regarded as a key resource for language processing (Evans, 2001), yet with the exception of a study by Hanson and Montgomery (2002), little

effort has been directed at determining the impact of attention deficits on language processing in SLI. The current study indicates that AD(H)D occurs with such high frequency in the persistent SLI population that it cannot be ignored. It therefore appears to be beneficial to document the presence of attention deficits in research participants and at least consider the potential impact of this important area on performance in language and memory tasks.

8.3 In Search of a Phenotype for Persistent SLI

The search for a phenotype for SLI is complex. Thus far, only expressive morphosyntax and phonological processing (as measured by nonword repetition), are consistently described as core language deficits viewed as central to SLI (Tager-Flusberg & Cooper, 1999). Results of the current study add another dimension to the interpretation of results regarding a phenotype for SLI. Both expressive morphosyntax and nonword repetition tasks require verbal output. This study has shown that individuals with persistent SLI have compromised speech output, particularly when task demands are high. One could argue that poor performance on morphosyntactic and memory tasks requiring verbal output could be due, in part at least, to poor speech abilities. It is therefore possible that what is inherited is not (only) poor morphosyntactic knowledge or poor phonological short term memory, but also poor speech abilities. Within the functional capacity viewpoint discussed in Chapter 3, all these deficits impact on processing capacity, constraining performance on verbal output tasks. This area bears further investigation to determine the extent of the influence of poor speech abilities on tasks purporting to measure morphosyntax or phonological short term memory.

The current study highlights the need to include an assessment of speech in describing the phenotype of SLI. As Rice (2004, p.208) proposed: "Current attention focuses on the need for greater precision in the language phenotype, for improved accuracy in the identification of affected children, and more precise description of the dimensions of affectedness". Results from this study suggest that a description of the language phenotype for SLI is not complete without considering speech abilities.

Results of this study suggest that poor speech abilities occur commonly enough in adolescents with persistent SLI to be regarded as part of the phenotype of the disorder. Of the participants with persistent SLI, 23 were in the Poor Speech group, while 22 obtained nonword repetition scores in the Children's Test of Nonword Repetition that were more than 1*SD* below the TD mean. These results suggest that poor speech abilities are as common as poor nonword repetition in this population. If nonword repetition is regarded as part of the heritable phenotype of SLI (Bishop, North & Donlan, 1995; Bishop, 2002a), the current study suggests that there is strong evidence for the need to investigate whether poor speech abilities also form part of this phenotype. However, poor speech abilities also occurred in participants with no family history of language or learning difficulties, suggesting that for at least some participants, these deficits were less likely to be related to genetic factors.

Based on results from the current study, there is strong evidence for a multifactorial etiology to persistent SLI. Some participants presented with only a significant family history of language or learning difficulties (29%), some presented with only a significant early history (13%), some presented with both genetic and early history factors (29%), while a substantial number (29%) presented with neither of these factors. Thus for a large number of participants, genetic factors did not appear to play a role. It therefore appears that the underlying biological (presumably neurological) factors leading to persistent SLI may be triggered either by genetic or environmental factors or both. Contrary to previous findings (Tomblin, Smith & Zhang, 1997), factors related to pregnancy and birth appear likely to play an etiological role in at least some individuals with SLI. It is probable that persistent SLI, which is presumably a more severe form of the disorder, has different risk factors than the SLI group as a whole, and particularly compared to resolving SLI, which was included in many previous studies on risk factors in the SLI population.

The high incidence of motoric deficits and AD(H)D points strongly to the presence of neurological deficits in persistent SLI which are specific not only to the language areas of the brain. It may be useful in future to investigate resolving and persistent SLI separately regarding the presence of these neurological factors,

to establish whether persistent SLI is more likely to include nonlinguistic deficits than resolving SLI.

This study confirmed that the SLI population lacks homogeneity and that group trends may not necessarily apply to individuals. There was substantial overlap of scores between the SLI and TD groups on the OME and SAB tasks, indicating that at least some SLI participants scored within the average range for TD participants. The wide range of scores even within a subtype of SLI (persistent SLI) provides support for the view that there may not be one phenotype for SLI. It is possible that different genes are implicated for different subtypes of SLI, each resulting in a different phenotype, and that even within subtypes there may be different phenotypes. As Tager-Flusberg (2004, p.44) stated, SLI is a disorder "…with heterogenous phenotypes that are likely to have a complex genetic basis." In fact, recent studies have even found striking overlaps among some subgroups of autism and SLI (Tager-Flusberg, 2004). Such a situation complicates genetics research in SLI, since, as Rice and Warren (2004) pointed out, advances in genetics necessitate precision in the measurement of the behavioural phenotypes. Furthermore, environmental influences may serve to influence the phenotype through an interface of genetics, the brain and the environment (Rice & Warren, 2004). The result may be that there are so many subtypes of SLI that subtyping is not useful either clinically or for research purposes, and that profiling of strengths and weaknesses may be more fruitful (Wilson & Risucci, 1986).

8.4 The Speech Assessment Battery (SAB) as an Assessment Tool

The SAB presents with a number of advantages as an assessment tool. The battery as a whole controls for linguistic and memory factors which enables the clinician to determine if poor performance is due to language or memory deficits, or truly reflects poor speech abilities. In contrast to most existing speech assessments, the demanding nature of the tasks and the detailed scoring allows for the detection of subtle speech deficits. The SAB measures not only the individual's ability to produce certain stimuli, but the amount of effort required to perform this task, thus providing an indication of automaticity of responses.

Administration of the SAB is relatively quick (15-20 minutes). Good split-half reliability has been demonstrated with the same age group used in the current study (Bean, 2006), suggesting that even shorter versions of the battery could be devised. Instructions are simple and the tasks do not appear threatening to the testee. With the exception of the Tongue Twister Task, no special materials are required, rendering this assessment inexpensive and portable.

The SAB in its current form has two major drawbacks. Firstly, it is reliant on citation tasks and thus needs to be supplemented by a task requiring language formulation to provide a valid assessment of speech (Kent, 1997). Secondly, transcription and scoring can be time-consuming, particularly when a testee has made many errors. However, with practice, much of the scoring (with the exception of the Tongue Twisters) can be done on-line and checked on tape afterwards.

Normative data for unimpaired children and adults must be obtained before the SAB can be used effectively as a clinical tool, but there is the potential for further application of the SAB in a number of populations.

The SAB has clinical utility in the assessment of older children (9 years and older) when traditional articulation and phonology assessment tools are no longer appropriate. The SAB would be useful to detect inconsistent errors once a child's phonetic inventory is complete. From attendance at professional fora, it is evident that clinicians are reporting an increasing population of paediatric clients who present with "indistinct", "slushy" or "mumbling" speech, but are finding that traditional oral motor assessments and speech assessments are inadequate to obtain a detailed description of these clients' speech or to plan intervention. The SAB may provide a solution to this difficulty, due to its sensitivity to inconsistent errors and its assessment of speech under demanding conditions.

The SAB can also be used for diagnosis and monitoring with individuals with neurogenic communication disorders who do not have overt dysarthria or apraxia of speech, yet who do present with speech difficulties. The SAB can be used for diagnostic purposes with, for example, individuals with Traumatic Brain Injury (TBI). The subtests of the SAB have been found to have good split-half reliability in adolescents (Bean, 2006), suggesting that after further research into

the reliability of the SAB, alternate forms of the battery can be used to monitor the effect of intervention. In view of its sensitivity to factors such as automaticity, monitoring, and context-dependent speech errors, the SAB can potentially also be used to monitor progressive disorders and post-concussion effects in sports players; while it may also play a role in monitoring the effects of medication in individuals with neurogenic or psychiatric conditions. In the medicolegal context, the SAB can be used to assess individuals with mild TBI, who report subjective awareness of changes in their speech, but whose speech difficulties cannot be measured by existing instruments.

8.5 Clinical Implications

Research into the speech difficulties of older children with SLI is still in its infancy, hence the clinical implications of the findings of this study are tentative.

8.5.1 Implications for Traditional Assessment and Intervention

Screening for SLI is a complex task. If, on every task used in the current study, at least some participants with SLI obtained scores in the average range for TD participants, one can conclude that no single instrument will reliably identify all individuals with SLI.

The fact that so many adolescents with SLI present with residual errors suggests that discharge criteria for intervention directed at sound errors with younger children may have to be reconsidered. Instead of using samples of spontaneous speech or simple naming tasks to determine if specific speech sound errors have been remediated as the sole criterion for discharge, clinicians should also consider using challenging tasks to evaluate speech production before terminating intervention. Perhaps intervention should not only be directed to the remediation of specific sound errors, but to general speech production abilities, particularly automaticity of production of phonologically complex utterances.

8.5.2 To Treat or not to Treat?

There are compelling reasons to consider providing treatment for the speech difficulties identified in this study.

Firstly, the fact that one third of the participants with SLI were reported to have speech difficulties by their caregivers indicates that their speech is poor enough to draw attention to itself. As Van Riper and Emerick (1984, p. 34) stated: "Speech is abnormal when it deviates so far from the speech of other people that it calls attention to itself, interferes with communication, or causes the speaker or his listeners to be distressed". Furthermore, two thirds of the participants with SLI were found to have substantially poor speech abilities (categorized as the Poor Speech Group), suggesting that speech difficulties are a real issue for this population and may interfere with communication.

Secondly, poor speech can impact on an individual's educational, social and vocational functioning. In an educational setting, adolescents with poor speech may struggle with oral presentations or group discussions and may be perceived negatively by their teachers. On a social level, such children may be teased by peers or be perceived negatively by their peer group. Poor speech abilities may affect vocational choices and could also affect employers' perceptions of an individual's abilities.

Thirdly, poor speech abilities may be a drain on resources, requiring the allocation of more resources to speech production and drawing resources away from other areas such as the planning of discourse, working memory or expressive syntax. As a result, poor speech abilities may impact on other aspects of communication and contribute to the adolescent with SLI's poor language performance.

8.5.3 How to Treat?

It is probably premature to offer guidelines for intervention for adolescents with SLI and poor speech, but some suggestions are worth investigating. A combination of drill work and compensatory strategies may be effective in addressing the speech difficulties of this population. It has been shown that speech errors can be reduced by reducing rate of speech (Taylor, 1990), indicating that this compensatory strategy may be useful. Practising difficult sound sequences may have value (Taylor, 1990), as speech has a skill component, hence practice increases the control and precision with which a movement is performed (Stoel-Gammon, 1998). Nonword stimuli may be useful in this type of

intervention, as the ability to deal with nonwords is an important skill for children who constantly have to deal with and learn new words (Rees, 2002) – all real words were at first nonwords. Intervention aimed at increasing the automaticity of production of complex sound sequences may reduce the amount of resources required for speech production, which would not only improve speech production, but may have a positive impact on language performance by freeing up resources.

Intervention aimed at simply improving oral motor skills cannot be justified, as no experimental literature attests to the effectiveness of these principles in teaching speech sounds (Smit, 2004). Furthermore, the primary difficulty in this population is not the production of specific sounds, but the production of complex sequences of speech sounds, hence it is unlikely that exercises aimed at improving muscle strength or coordination would be effective.

8.6 Implications for Research

The findings of this study indicate that further research should be conducted in a number of areas.

There is a shortage of normative data regarding the speech development of older children. While there is ample data regarding the acquisition of speech sounds, data is required regarding the mastery of complex sound sequences and the ability to produce acceptable speech output with increased demands on resources. Whether further data is obtained on the SAB, or other assessment batteries are developed, it is important to obtain data for a range of age groups in the typically developing population to facilitate diagnostic and intervention decisions.

At the same time it is also important to establish data regarding comorbidity of language and speech disorders in SLI. Rice (2004) identified the need to determine comorbidity of language and speech disorders at the time that language emerges, but it is equally important to investigate the impact of speech deficits throughout the language acquisition period. In order to do this, comorbidity data is required throughout the developmental period, including adolescence.

Intervention studies are necessary to determine if the speech problems identified by the current study are amenable to change. The effectiveness of

compensatory strategies and direct intervention strategies have to be determined with different age groups, while the effects of the concomitant language and memory deficits on therapy progress also have to be determined.

The interactions among speech, language and memory need to be explored in more detail. Specifically in the SLI population, the potential impact of speech deficits on morphosyntactic development should be investigated. The impact of increased task demands in terms of linguistic complexity on speech performance should also be explored.

Selection of participants with SLI for research studies needs to be considered carefully. Researchers need to aim for more consistency regarding the phonological output criterion, as the validity of empirical data is affected by variable application of this criterion. The fact that a large number of participants with SLI reported a history of phonological disorder indicates that Developmental Phonological Disorders are common in the persistent SLI subgroup, and that the exclusion of participants with DPDs from research studies leads to biased selection of participants. Furthermore, the materials used to screen for phonological output or motor speech deficits should be sufficiently demanding to identify inconsistent or context-specific deficits. Materials and procedures commonly used in current research would identify only the most overt DPDs and oral structural or functional deficits. Subtle speech and oral motor deficits which could impact on verbal output tasks would remain undetected.

The potential impact of speech output factors on performance in any task requiring verbal output can affect the validity of tasks used in research. In particular, tasks requiring the production of multisyllabic words, unfamiliar sound sequences (such as nonwords), or complex sound sequences (such as the consonant clusters commonly produced after the addition of grammatical morphemes) should be investigated to tease out the differential impact of speech factors versus the linguistic or memory factors under investigation.

Risk factors specific to certain subtypes of SLI should be investigated further, using longitudinal studies of large groups.

8.7 Conclusion

This study has demonstrated that one cannot consider language processing in adolescents with SLI without considering the final link in the language processing chain, namely speech production. Quite clearly, impaired speech production abilities could impact on other parts of the language processing chain. Within a resource-allocation framework, impaired speech production will reduce resources available for other aspects of language processing, suggesting that the syntactic and memory deficits typical of this population could be exacerbated by such speech deficits. Therefore, despite the absence of overtly diagnosed speech disorders in this population, clinicians and researchers would be short-sighted to ignore speech production deficits in this population. Apart from the implications for research in SLI, speech-language pathologists have a clinical obligation to their clients to treat all aspects of communication which are impaired and may therefore affect the client's ability to function in society. As Van Riper and Emerick (1984, p.3) stated:

"In our own…highly competitive, upwardly mobile…(society), verbal skill is greatly rewarded. We swim in a vast ocean of words all of our lives. Effective speech in such a society is of the utmost importance if one is to gain and maintain membership or to get the status and material possessions which are constantly held up to us as goals to be desired" (Van Riper & Emerick, 1984, p. 3).

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Appendix A: Ethics Clearance Certificate.

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 Bowker

CLEARANCE CERTIFICATE **PROTOCOL NUMBER** M03-08-08

PROJECT Speech Production in Adolscents with Specific Language Impairment

INVESTIGATORS Ms J Bowker

DEPARTMENT Speech Pathology & Audio, Wits University

DATE CONSIDERED 03-08-29

DECISION OF THE COMMITTEE Approved unconditionally

Unless otherwise specified the ethical clearance is valid for 5 years but may be renewed upon application
This ethical clearance will expire on 1 January 2008.

DATE 03-09-01 CHAIRMAN.....(Professor P E Cleaton-Jones)

* Guidelines for written "informed consent" attached where applicable.

c c Supervisor: Prof C Penn
Dept of Speech Pathology & Audio Wits University
Works2\Iain0015\HumEth97.wdb\M 03-08-08

Appendix B: Information, Consent and Assent Forms.

B1: Information and Consent Letter for Principals of Schools for Learners with Special Educational Needs.

Dear _____

Research Project

I am a doctoral student at the University of the Witwatersrand, and I am doing a research project on speech production in children with Specific Language Impairment (SLI). Specifically, my study is investigating whether some children with Specific Language Impairment still have subtle motor speech deficits, despite the fact that they do not have obvious articulation errors. Such speech deficits may impact on their performance on memory tests which involve the repetition of complex speech stimuli. Children may thus perform poorly on memory tests because of speech production difficulties, rather than memory deficits. The area I am studying has not been researched extensively, and it holds many implications for therapists who are assessing and treating children with SLI. Results of my study would thus be of benefit for all therapists working with children with Specific Language Impairment, not only Speech-Language Therapists, as it would increase their knowledge regarding the effect of speech production factors on assessment and therapy.

Many children with SLI have learning difficulties, and are therefore placed in remedial schools. I would like to obtain your permission to use learners from your school as participants for my study.

The study will involve the following: Parents of potential participants will be invited to complete consent forms and a preliminary background history form, to determine if their children are suitable for the study. Parents of children who are suitable, and who agree to participate, will be contacted telephonically to arrange appointments for testing. If you give consent, children will be tested at school, during school hours. However, if you do not want to consent to this, I will arrange to test the children at a place and time convenient to the parents. Testing sessions will last approximately three hours, and will include speech production tasks, memory tasks and language and auditory processing testing. Parents of children participating in the study will also be asked to complete a more detailed case history form at this time. Results from the assessment will be made available to parents. With the parents' consent, I will also make the results of individual learners available to the school. Once my study is completed, I will give the school a written summary of my results. I am also prepared to organise a verbal feedback session for interested staff members.

Should you agree to allow me to do the study at the school, the school will be involved in two ways. Firstly, I will ask you to distribute information and consent letters to the parents of all 13 year-old children who speak English as a first

language. Once these forms have been returned by parents, I will collect them from the school in order to contact relevant parents. Secondly, should parents give me permission to access their children's school records, I will need to see the learner's last school report, as well as results of previous speech-language and cognitive tests, in order to establish whether learners meet the criteria for my study. If you prefer that I do not have direct access to these records, I can give you a list of the information I require (primarily IQ scores and language test scores), and your staff can access the information for me.

Your school's participation is voluntary, and you are free to withdraw consent for the study at any time without any consequences. All information obtained from your learners and their parents will be treated confidentially, and participants will only be identified by number. If you are willing to allow me to do the study at your school, please complete the consent form below. If you would like any more information, please do not hesitate to contact me at the numbers below.

_____
Jeán Bowker
(H) 011-782-7848
(W) 011-717-4573/7
(Cell) 083-733-3554

I, _____, principal of _____ give Jeán Bowker permission to conduct her research study on speech production in children with Specific Language Impairment at this school. I understand that my school's participation in the study is voluntary, and that I am free to withdraw my consent at any time.

I agree to allow staff at the school to distribute information and consent letters to parents of potential participants. I also agree to give Jeán Bowker access to the children's school records, provided their parents give written consent. I understand that all information will be treated confidentially.

_____ _____
Principal Researcher

_____
Date

B2: Information and Consent Letters for Principals of Ordinary Schools.

Dear

Research Project

I am a doctoral student at the University of the Witwatersrand, and I am doing a research project on speech production in children with Specific Language Impairment (SLI). Specifically, my study is investigating whether some children with Specific Language Impairment still have subtle speech difficulties, despite the fact that they do not have obvious speech errors. Such speech difficulties may impact on their performance on some memory tests which involve the repetition of complex speech stimuli. Children may thus perform poorly on memory tests because of speech production difficulties, rather than memory deficits. The area I am studying has not been researched extensively, and it holds many implications for therapists who are assessing and treating children with SLI. Results of my study would thus be of benefit for all therapists working with children with Specific Language Impairment, not only Speech-Language Therapists, as it would increase their knowledge about the effect of speech production factors on assessment and therapy. The study also holds benefits for children in mainstream schools, as results of my study can help therapists to diagnose speech and language disorders more accurately, and possibly identify problems earlier. As part of my study, I need to obtain information about the speech production of normal adolescents. I would like to obtain your permission to use learners from your school as participants for my study.

The study will involve the following: Parents of potential participants will be invited to complete consent forms and a preliminary background history form, to determine if their children are suitable for the study. Parents of children who are suitable, and who agree to participate, will be contacted telephonically to arrange appointments for testing. Testing will take place at school, at a time convenient to the school, if you are willing to consent to this. If you prefer that testing is not done at school, I will contact parents telephonically to arrange testing at a place and time convenient to them. Testing sessions will last approximately 30-60 minutes, and will include speech production tasks and memory tests. Parents of children participating in the study will also be asked to complete a more detailed case history form at this time. Results from the assessment will be made available to parents. If, during the course of my testing, I find that a child may have hearing, speech and/or language problems, I will inform his/her parents, and refer them for appropriate services. With the parents' consent, I will also make the results of individual learners available to the school. Once my study is completed, I will give you a written summary of my results. I am also prepared to organise a verbal feedback session for interested staff members.

If you agree to allow me to do the study at the school, the school will be involved in two ways. Firstly, I will ask you to distribute information and consent letters to the parents of all 13-year old children who speak English as a first language.

Once these forms have been returned by parents, I will collect them from the school in order to contact relevant parents. Secondly, should parents give me permission to access their children's school records, I will need to see the learner's last school report, in order to establish whether learners meet the criteria for my study. If you prefer that I do not have direct access to these records, I can give you a list of the information I require (primarily their academic history and recent marks), and your staff can access the information for me.

Your school's participation is voluntary, and you are free to withdraw consent for the study at any time without any consequences. All information obtained from your learners and their parents will be treated confidentially, and participants will only be identified by number. If you are willing to allow me to do the study at your school, please complete the consent form below. If you would like any more information, please do not hesitate to contact me at the numbers below.

_____
Jeán Bowker
(H) 011-782-7848
(W) 011-717-4573/7
(Cell) 083-733-3554

I, _____, principal of _____ give Jeán Bowker permission to conduct her research study on speech production in children with Specific Language Impairment at this school. I understand that my school's participation in the study is voluntary, and that I am free to withdraw my consent at any time.

I agree to allow staff at the school to distribute information and consent letters to parents of potential participants. I also agree to give Jeán Bowker access to the children's school records, provided their parents give written consent. I understand that all information will be treated confidentially.

_____ _____
Principal Researcher

_____
Date

B3: Information and Consent Letters for Parents, with Preliminary Case History Form.

Dear Parent.

My name is Jeán Bowker, and I am a doctoral student at the University of the Witwatersrand. I am doing research on speech production in children with language difficulties. I am trying to find out if older children with language difficulties have problems with difficult speech tasks, such as tongue twisters, even if they do not have specific speech errors. Children who find such speech tasks difficult, may do poorly on some memory tests because of their poor speech, rather than their poor memory. Information from my study would thus be important to any therapists assessing and treating children with language difficulties. Results from my study may change the way that therapists assess and treat memory problems in children with language difficulties. As part of my study, I need to test children who have a history of language difficulties, as well as children who have never had any language problems.

I would like to invite your child to participate in my study. If you agree to allow him/her to participate, the study will involve the following:

- A hearing screening test may be done under earphones to make sure your child's hearing is normal;
- Speech testing, which includes an examination of your child's mouth, and the repetition of long words, tongue twisters, and nonsense words;
- Memory tests, which includes the repetition of words or numbers, as well as the naming of pictures.

This testing should take approximately 30-60 minutes and would need to be tape-recorded.
If your child has a history of language difficulties, I would also do further language and auditory processing testing, which would take an additional two hours. These tests would look at your child's vocabulary, grammar, awareness of sounds in words, interactional skills, and conversational ability.

Testing would be arranged at a time and place convenient to you. At this time, I would also ask you to complete a detailed background history form, to find out more about factors related to language difficulties.

In order to find out if your child is suitable for my study, I would need some preliminary background information from you, and from his/her school reports. If your child has a history of language difficulties, I would also need to obtain information about his/her results on previous language and intelligence tests.

Any information provided by you or by his/her school, will remain confidential. I will not identify your child by name when I report his/her results in my research report, and I will not disclose your child's test results to anyone else. I will give you a brief written report about your child's test results on conclusion of my study. You are also welcome to contact me for a personal feedback session. If you agree, I would also give results to the school. Particularly in the case of children with language difficulties, these results could help the school to plan future intervention for your child.

Your child's participation in this study is voluntary. If you or your child choose not to participate, there will be no consequences for your or your child. You or your child are also free to withdraw from the study at any stage without any consequences.

If you decide to participate in this study, I ask you to do the following:

- Complete the consent forms on the next page;
- Complete the brief background history form to help me determine if your child is suitable for the study;

Place both forms in the envelope provided, and return it to your child's class teacher.

Thank you for your time. If you have any questions, please do not hesitate to contact me at the numbers provided below. If you agree to allow your child to participate, I will contact you within the next two weeks to let you know if your child has been selected for the study, and to arrange testing sessions.

Jeán Bowker
(Cell) 083-733-3554 (H) 782-7848 (W) 717-4573/7

I, _____, parent/guardian of _____, agree to the following:

(Please circle yes or no for each question.)

I agree to allow my child to participate in Jeán Bowker's study.	Yes	/	No
I agree to complete a detailed case history questionnaire about my child.	Yes	/	No
I give permission for the researcher, Mrs. Jeán Bowker, to have access to my child's previous assessment reports at school.	Yes	/	No
I agree to give the researcher, Mrs. Jeán Bowker, access to copies of my child's previous assessment reports that are not in the school file.	Yes	/	No

I give permission for my child's test results to be given to the school.
to the school.
I give permission for my child's test results to be given Yes / No
to the school.

If you have agreed to complete a detailed case history questionnaire, please indicate how you would like to receive the questionnaire:
To be sent and collected by my child's school teacher Yes/No
To be received and returned via email Yes/No
If you have selected the email option, please provide your email address below.
_____
I understand that my participation in this study is voluntary, and that I may withdraw my child from the study at any time without any penalties to myself or my child. I understand that if I have any questions, I am free to approach Jeán Bowker. I also understand that all the information that I or my child's school provide about my child will remain confidential.

_____ _____
Signature Date

Contact details:

Name of parent/guardian: _____
Name of child: _____
Contact telephone number: (H)_____ (W) _____
(Cell) _____
Email:_____
Postal Address: (For test results)
_____
I, _____, parent/guardian of _____, agree to give permission for my child's testing sessions to be tape recorded for the purposes of Jeán Bowker's study. (Please circle the correct response)

Yes / No

All tape recordings will be destroyed once the study is completed.

Dear Parent.

If you have agreed to allow your child to participate in the study, I would appreciate it if you could answer the questions below. The children who participate in my study must meet specific criteria. To help me decide if your child meets these criteria, I need the following information:

Your child's name: _____
Your child's date of birth: _____
Your child's school: _____
Your child's current grade level: _____
Your child's home language: _____
Does your child speak any other languages? Yes / No
If yes, please provide details:
_____
_____
_____

Has your child ever been diagnosed with a hearing loss? Yes / No
If yes, please provide details:
_____
_____

Has your child ever been diagnosed with a neurological condition, such as cerebral palsy or epilepsy? Yes / No
If yes, please provide details:
_____
_____

Does your child have any other illnesses or conditions which may interfere with his/her learning? Yes / No
If yes, please provide details:
_____
_____
_____

Has your child ever been tested by a psychologist or a speech-language therapist? Yes / No
If yes, please provide the name of the professional(s) and the date(s) of the assessment(s):
_____
_____

Has your child ever repeated a grade? Yes / No
If yes, please provide brief details:
_____
_____

Thank you for taking the time to complete this form. I will contact you within the next two weeks to let you know if your child will be part of my study.

B4: Information and Assent Form for Participants

Hello.

My name is Jeán Bowker. I am doing a project on children's speech. I want to find out how children of your age manage to say difficult things like tongue twisters. This information would be very helpful to therapists working with children.

If you are part of my study, I will do some tasks with you. The tasks will take about one hour (*for participants with typical language development)*/three hours (*for SLI participants)*.
First I will test your hearing. You will wear earphones, and you will have to tell me when you hear beeps through the earphones.
Next I will look in you mouth and ask you to move your tongue and lips to make sure that you can say the words I am going to give you. After that I will ask you to say some long words, to say some tongue twisters, and to say some nonsense words.
Next we will do some memory tasks, where I will ask you to repeat some things after me.
(*For SLI participants, also add the following: We will also do some language and listening tests, like you've done with your speech therapist. For example, I'll ask you to point to pictures, describe pictures, answer questions, or make up sentences for me.)*

If there is anything you do not understand, please ask me. You do not have to do these tasks with me, and you can ask me to stop at any time. You will not get into trouble if you do not work with me. If you want to work with me, tick the box below and write your name.

I agree to be part of Jeán's project. ☐

My name is: _____

Appendix C: Risk Factor Questionnaire.

Dear Parent.

Thank you again for agreeing to let your child participate in my study. As part of the study, I need some more background information to help me understand your child's speech and language better. I would therefore appreciate it if you fill in this questionnaire. Please try to answer questions in as much detail as you can. If you are unsure about anything, please phone me, and I will be happy to answer your questions. My contact numbers are:

Cell: 083-733-3554 Work: 717-4573/7

This information will be treated confidentially, and will not be shown to your child's school. In my thesis your child will not be identified by name. Therefore I would be the only person who has access to the information you provide.
Once you have completed the questionnaire, please place it in the envelope provided, and return it to the school secretary OR if you have received this by email, please return it to sender.

Jeán Bowker

Part 1: Background Information

Please provide information about the child's **biological parents.**

Father's age:		Mother's age:	
Father's home language(s):		Mother's home language(s):	
Father's highest educational level		Mother's highest educational level:	
Marital status of biological parents:			

Part 2: Early History

Duration of pregnancy:		
Mother's health during pregnancy		
Were there any complications during pregnancy?	Yes / No	If yes, please provide details.
Were there any complications during labour?	Yes / No	If yes, please provide details.
Did your child receive any special medical attention after birth (e.g. incubator, ventilator)?	Yes / No	If yes, please provide details.
Describe your child's health at birth?		

Has your child ever had any feeding difficulties (For example, poor sucking, excessive vomiting, choked easily, disliked food textures?	Yes / No	If yes, please provide details.	
Is your child currently a messy eater (for example, often has crumbs around his/her mouth; often chokes while eating)?	Yes / No		
At what age did your child:	Sit:	Crawl:	Walk:
At what age did your child:	Say the first word:		Start saying sentences

Part 3: Medical History

Has your child ever had any ear infections?	Yes / No	If yes, how often has he/she had ear infections?
Has your child ever had a burst eardrum?	Yes / No	If yes, at what age(s) did this happen?
Has your child ever had grommets inserted?	Yes / No	If yes, at what age(s) were grommets inserted?
Has your child ever been diagnosed as having an attention deficit?	Yes / No	If yes, please provide more information. For example, who made this diagnosis; what type of attention deficit does your child have; at what age was he/she diagnosed; etc.
Is your child currently on any medication?	Yes / No	If yes, please indicate what medication he/she is on, and the reason he/she is taking this medication.
Has your child ever had any severe illnesses or been hospitalised for any reason?	Yes / No	If yes, please provide details about the nature of the illness/hospitalisation, and the age at which this happened.

Part 4: Family History

Has this child's biological mother ever had any of the following:	
Difficulty in producing speech sounds as a child?	Yes / No
Difficulties with grammar or vocabulary as a child?	Yes / No
Learning difficulties at school?	Yes / No
Did she ever attend speech-language or remedial therapy?	Yes / No
If you have answered "yes" to any of the questions above, please provide details below.	
Has this child's biological father ever had any of the following:	
Difficulty in producing speech sounds as a child?	Yes / No
Difficulties with grammar or vocabulary as a child?	Yes / No
Learning difficulties at school?	Yes / No
Did he ever attend speech-language or remedial therapy?	Yes / No
If you have answered "yes" to any of the questions above, please provide details below.	

Has any of this child's siblings (brothers, sisters or half-brothers or half-sisters) ever had any of the following:	
Difficulty in producing speech sounds as a child?	Yes / No
Difficulties with grammar or vocabulary as a child?	Yes / No
Learning difficulties at school?	Yes / No
Did he/she ever attend speech-language or remedial therapy?	Yes / No
If you have answered "yes" to any of the questions above, please provide details below. For each person you discuss below, please indicate their relationship to the participant in the study, and describe their speech, language or learning difficulties.	

Have any members of this child's extended family (aunts, uncles, cousins, grandparents, etc.) had any speech, language or learning difficulties?	Yes / No
If so, please provide details below.	

Part 5: Educational History

In which grade is your child currently?		
Has he/she ever repeated a grade?	Yes / No	If yes, which grade(s) were repeated?
If your child is not currently in a mainstream school, when did he/she transfer to a school which caters for children with specialised educational needs?		

Please describe your child's current academic strengths and difficulties.
How does your child cope socially?

Part 6: Speech & Motor Development

Has your child ever attended speech/language therapy?	Yes / No	If yes, please provide details (i.e. when did he/she attend therapy; why did he/she attend therapy; how long did he/she attend therapy).
At what age did your child speak clearly enough that people outside the family could understand him/her?		
When your child was little, did he/she have difficulty saying any particular speech sounds (for example, "s" or "r")?	Yes / No	If yes, please give examples of sounds or words your child could not say.
Did your child have difficulty with just one or two sounds, or several different sounds? Please give examples, if possible.		
If your child had difficulty with several sounds, did he/she seem to have consistent patterns of sounds that were difficult? For example, did the child leave off all the last sounds in words, or swop sounds consistently?		
Could you predict which words your child would mispronounce, and how he/she would say these words?	Yes / No	If yes, can you give an example?
Did preschool teachers or relatives ever comment that your child's speech seemed to be particularly unclear?	Yes / No	If yes, please give details.
By what age did your child pronounce all the speech sounds correctly all the time (including "s", "r" and "ch")?		
Does your child ever mispronounce words now?	Yes / No	If yes, please give details.
If your child still occasionally mispronounces words, does he/she have specific sounds that are difficult?	Yes / No	If yes, please give examples.
Does your child have difficulty pronouncing long words?	Yes / No	If yes, please give an example.

Does your child have any difficulty with gross motor movements (running, skipping, jumping, riding a bicycle, ball sports)?	Yes / No	If yes, please describe this difficulty.
Does your child have any difficulty with fine motor movements (for example, untidy handwriting, difficulty cutting with scissors or sewing, difficulty picking up or manipulating small objects)?	Yes / No	If yes, please describe this difficulty.
Has your child ever been described as clumsy by teachers?	Yes / No	
Has your child ever attended Occupational Therapy?	Yes / No	If yes, please describe why he/she attended Occupational Therapy.

Thank you for taking the time to fill out this form. I really appreciate your cooperation. Please contact me if you have any questions after filling out the form.

Appendix D: Description of Pretests and Pilot Study

D1: Pre-Test 1: Recorded versus Live Voice Presentation of Stimuli.

The first pre-test was conducted on a group of young adults who speak English as a first language.

Aim: To determine if taped stimuli for the nonwords from the Children's Test of Nonword Repetition (Gathercole, 1995) and the Nonsense Word Repetition Task (Kamhi & Catts, 1986) were intelligible.

Participants: Ten participants were recruited by placing notices on student noticeboards at the University of the Witwatersrand. The notices explained the purpose of the study and invited students to participate. Participants had to meet the following criteria:

Language*:* Participants had to be first language speakers of English, to avoid the effects of accent on speech perception.

Hearing*:* Participants had to have normal hearing, to avoid the effects of hearing loss on speech perception.

Intelligence: Participants had to be of average or above average intelligence to ensure that they would understand the task.

Students who responded to the notices were given an information sheet explaining the study and were asked to provide written consent. Once they provided consent, they were asked to report on their home language and hearing status. It was assumed that students at a tertiary education setting would meet the intelligence criterion.

All ten students were female first year students registered for the degree B.A. (Speech & Hearing Therapy). At this stage of their training they had not yet done a course in phonetics and had no exposure to transcribing speech samples. They had also not had any exposure clients with speech problems. They were therefore regarded as untrained listeners. The participants met all the stated selection criteria.

Procedures: Stimuli consisted of the Nonsense Word Repetition Task (Kamhi & Catts, 1986) and the Children's Test of Nonword Repetition (Gathercole, 1995). Stimuli were recorded in a soundproof room using a Sanyo Compact

Cassette Recorder (TRC1130) and TDK B60 Brilliant cassettes. The stimuli were recorded at five second intervals to allow time for transcription, in the case of the pilot study, and for repetition, in the case of the primary study. Participants were provided with transcription sheets, containing instructions and numbered spaces in which to transcribe the words. The participants were seated in a quiet room in the University Speech and Hearing Clinic, either singly or in groups of not more than four students. The stimuli were then played using the same recorder used for recording the stimuli. After participants had transcribed three words, the researcher paused the tape to ensure that it was being played at a comfortable loudness level for the participants. Participants were allowed to request that the tape be paused if necessary. However, none of the participants made this request. Approximately 10-15 minutes were required for the participants to transcribe all the stimuli.

Data Analysis: Each transcription sheet was scored manually. As none of the stimuli were real English words, the transcriptions could not be scored according to spelling. Responses were thus read aloud to determine if the phonetic structure of the word matched the target stimulus. Once sheets were scored, a percentage score was obtained for each task.

Results: On the Nonsense Word Repetition Task, participants obtained a mean score of 66.7%, with a range of 36.7%-80%. On the Children's Test of Nonword Repetition, participants obtained a mean score of 66.25%, with a range of 55%-80%.

Conclusions: It was apparent that these typical young adults had great difficulty perceiving the taped stimuli. As none of the participants obtained a score over 80%, and most of them made errors on at least a third of the words, it was decided that it would be better to present the stimuli live, where participants would have the additional support of visual cues provided by the tester's articulators.

D2: Pilot Study: Instruments and Instructions.

Pilot studies were conducted on one participant with typical language development and three participants with Specific Language Impairment.

Aims: The primary aim of this pilot study was to determine if the test battery selected was appropriate and would meet the aims of the study. Sub-aims included:

- To determine the time period required for the administration of the full test battery;
- To establish whether the instructions used for tasks required modification;
- To determine if the series of tasks designed to measure speech production was sensitive enough to identify children with subtle speech deficits;
- To establish whether the method proposed to analyse speech errors was efficient, comprehensive and accurate;
- To determine whether the battery of tests selected to assess memory and language functioning was sensitive to deficits in this age group;
- To establish whether the questions on the case history questionnaire were clear and elicited the required information;
- To determine the best method of administering the case history questionnaire.

Participants: Participants for the pilot study had to meet the following criteria:

Age*:* Participants had to be in approximately the same age range as the participants of the planned study. Children between the ages of 11 years 6 months and 14 years 6 months were recruited.

School*:* Participants had to attend the schools from which children would be recruited for the planned study, to control for educational background, and to some extent, socioeconomic status.

Other*:* With the exception of the criterion with regard to neurological status, participants also had to meet the selection criteria outlined above for the main study.

Participants were selected using the same selection procedure outlined above for the main study. Four children participated in the pilot study. All four children

were males from one government school for Learners with Special Educational Needs (LSEN). The participants are described in Table D1 below.

Table D1: Description of participants in pilot study.

Participant	Age	Verbal Quotient	Nonverbal Quotient	Full Scale Quotient	IQ Test	Comments
P1	13y2m	Average	Average	Average	WISC-R[44] Nov 1999	Petit mal epilepsy. AD(H)D.
P2	13y1m	Average	Average	Average	JSAIS[45] Oct 1998	Repeated Grade 1. Petit mal epilepsy. AD(H)D.
P3	14y1m	Below Average	Average	Below Average	SSAIS-R[46] June 2000	Irlen Syndrome. Repeated Grade 3.
P4	11y8m	High Average	Above Average	High Average	SSAIS-R July 2003	Behaviour difficulties.

Procedures

Each participant was tested during a single session in a quiet room at the school after school hours. Presentation of tests was randomized across and within the three test batteries i.e. speech assessment battery, memory battery and language battery. The batteries used in the pilot study consisted of the following measures:

Speech Assessment Battery*:* Oral Motor Evaluation (OME), Multisyllabic Word Repetition, Nonsense Word Repetition, Phrase Repetition, Sentence Repetition, Counting Task, and Tongue Twisters.

Memory Assessment Battery*:* Word Series (CAS); Sentence Repetition (CAS); Sentence Questions (CAS); Naming Speed Test – Pictures (PhAB); and Nonword Repetition.

Language Assessment Battery*:* Listening Vocabulary (TOAL-2); Understanding Ambiguous Sentences (TOLC); Formulated Sentences (CELF-R); Word Associations (CELF-R); Spoonerisms (PhAB); and narrative discourse. Sessions with P1 and P2 included the Word Structure and Sentence Structure subtests of the CELF-R, but these were replaced by the Listening Grammar subtest of the

[44] Wechsler Intelligence Scale for Children – Revised (WISC-R)
[45] Junior South African Intelligence Scale (JSAIS)
[46] Senior South African Intelligence Scale – Revised (SSAIS-R)

TOAL-2 for the last two participants. The sessions with P1 and P2 also included a procedural discourse sample, but this was not done with P3 and P4.

Results

Results will be described in accordance with the aims for the pilot study outlined above.

Length of Test Session: The duration of the test sessions ranged from 80 minutes to 105 minutes to complete the full test battery. Even the participants with AD(H)D were able to complete the test battery, provided tasks were varied, and the children were allowed short breaks within the session. It was therefore decided that it would be feasible to test the adolescent participants in a single session.

Test Instructions: For the majority of tasks, instructions were found to be easily understood and the participants did not experience difficulty in performing the required tasks. The exceptions were the Tongue Twister task and the narrative discourse task.

Initially the tongue twisters were presented in written format in order to aid recall of unfamiliar tongue twisters. The researcher rehearsed each stimulus with the participants until they could remember the words. However, this was found to be too difficult for P1 and P2, and it was clear that the participants had difficulty remembering the tongue twisters. The Tongue Twister task was then adapted to include a picture stimulus in addition to the written sentence. P3 and P4 were tested using the adapted stimuli. The participants coped much better and did not appear to have significant difficulty in remembering the stimulus sentences.

Narrative discourse was elicited using picture sequence cards. Initially the narrative discourse task was designed to allow the researcher to provide a model by telling a story about one set of picture cards before asking the participant to generate a narrative. However, it was clear that these adolescent participants did not want a model. Two of the participants refused to listen to the model before providing their own narrative. Participants were therefore given two opportunities to generate a narrative with the aid of picture sequence cards: One narrative with

picture cards visible, and a second narrative, using new picture cards, after the cards had been removed from view.

Speech Battery: Results for the speech battery are presented in Table D2.

Oral Motor Evaluation (OME)*:* The evaluation checklist was found to be comprehensive and could identify participants with structural or functional abnormalities of the articulators. For example, P4 presented with an overbite, overlapping dentition, sequencing difficulties, and difficulty in sustaining phonation. His OME score was markedly poorer than the other participants' scores.

Table D2: Results of pilot study on the Speech Assessment Battery.

Task		P1	P2	P3	P4
OME (number of structural or functional abnormalities)	Structure	1	0	1	2
	Function	0	0	2	1
	Speech Function	1	1	1	7
	Total	2	1	4	10
Multisyllabic Words (number of errors)		3	12	9	15
Nonsense Words (number of errors)		6	9	7	12
Phrase Repetition (number of errors)		3	4	11	13
Sentence Repetition (number of errors)		5	9	9	8
Counting Task (number of errors)		0	0	0	1
Tongue Twisters (Number of errors)		Not scored. Task was too difficult and was not completed	26 errors Rate: 125 s	62 errors Rate: 151s	93 errors Rate: 223s

Multisyllabic Word List*:* Scores ranged from three to fifteen errors on this 45-item task. P1, who was subjectively rated as the participant with the best speech production, obtained the lowest error score on this task, while P4, who subjectively had many speech production errors, obtained the poorest score on this task. Scores on the multisyllabic word list thus matched clinical impressions of the participants.

Nonsense Word Repetition: Scores ranged from six to twelve errors on this 30-item task. The percentage error scores were higher than those obtained on the Multisyllabic Word List. Such a discrepancy was anticipated, in view of the higher perceptual and memory demands of the Nonsense Word Repetition task. Results on this task followed a similar pattern to those obtained on the Multisyllabic Word List, with P1 obtaining the best scores, and P3, P2 and P4 following in order of severity.

Phrase Repetition*:* Scores ranged from three to thirteen errors on this 35-item task. The results thus had a similar range to those obtained on the Multisyllabic Word List.

Sentence Repetition: Scores ranged from five to nine on this 10-item task. The smaller range of scores may reflect that this task is easier in terms of speech production, because of contextual cues and the effects of co-articulation.

Counting Task*:* The counting task required participants to count from sixty to seventy. It was not sensitive to speech production errors in this population. Only one of the participants (P4) made an error on this task. Considering P4's poor performance on all the other tasks, it appears as if a participant would have to present with a very severe speech deficit in order to make errors on this task.

Tongue Twisters*:* The mode of presentation and the list of tongue twisters were changed after P1 and P2 completed their tests. Results could therefore not be compared directly across the four participants. However, while P3 and P4 both made a substantial number of errors on this task, there were clear differences between the two participants, both with regard to number of errors and rate of response, suggesting that this task allows for a range of performance.

Other: The aim of the Other category was to note speech errors which occurred during any other tasks during the test session. P2, who had notably poor speech production, presented with six such errors during the CAS subtests. However, none of the other participants presented with such errors. It was decided not to include the Other category in the main study.

Discussion of Results Obtained on the Speech Assessment Battery

Participants who met the diagnostic criteria for SLI performed worse than P1, who did not present with SLI. Within the SLI group, the younger participant performed much worse than the older participants. When considering the range of scores across participants, it appears as if the speech assessment battery can detect speech production difficulties, and that the battery is sensitive to a range of speech production abilities. The exception to this, was the Counting Task, which was not

deemed sensitive enough in this population. There was some concern that the Speech Assessment Battery relied primarily on repetition tasks.

Analysis of Speech Errors: Speech production errors were initially classified according to the phonological process categories described by Kamhi and Catts (1986). However, this list of categories was found to be inadequate for the purposes of this study. The participants presented with some unanticipated features of speech production, such as sound and syllable repetitions, revisions and word substitutions. These categories had to be included in the list of speech errors to be coded. The researcher therefore devised her own list of categories for analysis of speech errors. The final list of speech error categories which were used for the study are presented in Appendix J. P3 and P4's errors on the speech assessment battery were analysed using the revised list of speech error categories. The list was found to be comprehensive and user-friendly.

Memory and Language Assessment Batteries: Results for the memory and language assessment batteries are presented in Table D3. P2 reportedly presents with behavioural difficulties at school. He refused to complete the test batteries, thus not all tests were administered during his testing session.

Table D3: Results of pilot study on memory and language assessment batteries.

Task	P1	P2	P3	P4
Word Series (Scaled Score)	9	9	11	8
Sentence Repetition (Scaled Score)	10	8	9	9
Sentence Questions (Scaled Score)	10	6	12	12
Naming Speed – Pictures (Standard Score)	88	80	82	86
Nonword Repetition (Raw Score out of 40)	37	36	35	29
Listening Vocabulary (Scaled Score)	9	5	8	10
Listening Grammar (Scaled Score)	NA	NA	10	11
Understanding Ambiguity (Scaled Score)	12	5	6	11
Word Structure (Scaled Score)	14	11	NA	NA
Sentence Structure (Scaled Score)	12	10	NA	NA
Formulated Sentences (Scaled Score)	9	Not administered	8	5
Word Associations (Scaled Score)	17		12	16
Spoonerisms (Standard Score)	89		110	97
Narrative Quality (Rating out of 18)	14	5	9	13

Word Series, Sentence Repetition and Sentence Questions: Participants understood the task requirements easily. It was felt that this section of the test battery allowed for a range of performance, and was sensitive to memory deficits.

Naming Speed-Pictures: Participants obtained fairly low scores on this subtest, with scores ranging from Low Average (P1 and P4) to Below Average (P2 and P3). Rapid picture naming has been linked to poor reading performance (Wilson & Cline, 1995), and such low scores could perhaps be expected from children in a school for Learners with Special Educational Needs.

Nonword Repetition: Scores ranged from 29 (72.5%) to 37 (92.5%) on this 40-item test. Preliminary examination of the results suggested that:

- The participant with the most abnormalities on the OME, obtained the lowest Nonword Repetition score.
- The participant with the fewest speech errors on the speech assessment battery, obtained the highest Nonword Repetition score.
- The number of problems noted on the OME appear to have some relationship with the number of errors noted on the Nonword Repetition task.

The preliminary results from the pilot study thus suggested that there may be a relationship between speech production difficulties and nonword repetition.

Listening Vocabulary: Scores obtained for this subtest ranged from 5 to 10, suggesting that the test would be sensitive to a range of performance.

Understanding Ambiguity: This task appeared to be particularly sensitive to deficits of higher-level language, as participants either scored very poorly (P2 and P3), or scored within the average range (P1 and P4).

Sentence Structure, Word Structure and Listening Grammar: P1 and P2 were assessed using the Sentence Structure and Word Structure subtests of the CELF-R. Both participants clearly found these items easy, and obtained high scores on these subtests, despite P2's obvious language difficulties. These subtests were therefore deemed not to be sensitive enough to adolescent language deficits, and the Listening Grammar subtest of the TOAL-2 was used with P3 and P4 instead. While both participants obtained average scores on this subtest, results appeared to fit with the results obtained on other language tests. Subjectively, both

participants found this task challenging. The Listening Grammar subtest was therefore felt to be a more appropriate measure of receptive syntax for this population.

Formulated Sentences: Participants obtained scaled scores ranging from 5 (Below Average) to 9 (Average). This test was therefore found to be an appropriate measure to assess expressive syntax and semantics.

Word Associations: Participants' scores for this test were high, with all scores falling in the High Average to Superior ranges. It was decided to retain this test as a measure of spontaneous speech production at word level. All the tasks included in the speech assessment battery involve an element of repetition, and are thus reliant on working memory. The Word Associations test requires the participant to generate a list of words spontaneously, and could thus provide an indication of the participants' speech production without repetition.

Spoonerisms: This task appeared challenging for the adolescents involved in the pilot study and was thus retained as a measure of phonological awareness.

Discourse: Two samples of narrative discourse were elicited from each participant, using sequence cards as a stimulus. It was decided to use sequence cards rather than a personal narrative in order to provide some consistency across participants. The discourse samples were analysed using the narrative analysis described by Catts and Fey (2001) which yields a rating out of 18 for quality. During P1 and P2's test sessions, a procedural discourse sample was also obtained. However, after analyzing results it was felt that these samples did not add more information than was already obtained from the narrative samples. Procedural discourse samples were therefore removed from the assessment battery.

Risk Factor Questionnaire: Parents of participants were able to complete the risk factor questionnaire with ease, and provided all the necessary information. The format of the questionnaire was thus deemed to be adequate. Parents were given the option of returning the questionnaire via email, or the questionnaire was given to the participant on the day of testing. The participants' parents could then return the questionnaire in a sealed envelope via the school teacher. One parent selected the email option, and returned the questionnaire within a week. The other three

parents requested that the questionnaire be given to their child. Only one of these three questionnaires was returned, suggesting that this method of distribution may be problematic on a large scale. It was therefore decided to include a third option, whereby the questionnaire would be administered telephonically, should parents fail to return the questionnaire as requested.

Conclusions and Recommendations

After the pilot study, the following recommendations were made regarding the test batteries and the data collection procedures:

- Testing could be conducted in a single session, although participants may have to be given short breaks during testing.
- Instructions were largely adequate. The Tongue Twister task was adapted to include picture stimuli. The narrative discourse task no longer included a modeled narrative, but two samples of narrative discourse were elicited from participants.
- Most of the speech assessment tasks included in the preliminary test battery were found to be sensitive to speech production deficits in this population. The exception was the Counting Task, which was excluded from the assessment battery. As the Speech Assessment Battery is heavily reliant on repetition responses, it was decided to devise a naming task to elicit complex articulatory sequences, and to administer the task to the first group of participants, in order to determine its usefulness.
- The list of categories used to classify speech errors was modified and expanded.
- The memory test battery was found to be adequate, and remained unchanged.
- The language test battery was adapted, with the Listening Grammar subtest of the TOAL-2 being substituted for the Sentence Structure and Word Structure subtests of the CELF-R. The other components of the language assessment battery were retained, with minor modifications to the elicitation technique used for narrative discourse.

The risk factor questionnaire did not require modification. It was decided to introduce a third method of obtaining case history information, i.e. a telephonic interview with parents who did not return the initial questionnaire.

D3: Pre-Test 2: Repetition versus Naming/Delayed Imitation Responses.

The speech tasks used in this study were primarily reliant on repetition responses. As repetition is not an optimal elicitation technique, the second pre-test was administered to participants in the study to determine if at least one naming task could be included in the test battery. A naming task would reduce reliance on working memory. In some respects, this was not a true pre-test, as the naming task was administered to the first group of participants during the course of data collection, rather than prior to data collection. However after the initial pilot study, it was felt that it would be useful to attempt to include a naming task.

Aims: To determine if multisyllabic words with complex articulatory patterns could be elicited effectively using a naming or delayed imitation task.

Participants: The first group of 29 participants in the study were involved in this task. Of these, 16 participants had typical language development and 13 participants presented with SLI. The selection criteria and procedures outlined for the study were used to recruit participants.

Procedures: A naming task was devised whereby a sample of words from the Multisyllabic Word List were illustrated using ClipArt. As many of the words on the list were abstract and thus difficult to represent visually, additional words were included, such as "anemone", "hippopotamus" and "stethoscope". In total, the task consisted of twenty pictures. However, the difficulty remained that many of these words were fairly abstract, thus pictures did not elicit an immediate accurate naming response. Furthermore, many of these words required advanced semantic knowledge, and not all participants knew the words. Thus the task was adapted to involve both delayed imitation and a written stimulus. The tester would read through all the words once. Participants could request repetition of any words they did not know. Once participants were satisfied that they knew all the words, they would name all twenty pictures without further assistance from the tester. If participants requested additional repetition of a stimulus, their response was coded as "No Response", regardless of the accuracy of their response.

Results: This task did appear to indicate differences in performance between participants with SLI and those with typical language development. However, these results were not felt to be reliable for a number of reasons:

- Some participants requested many more repetitions of stimuli than others, ranging from 0 to 8 items repeated. Thus not all participants had the same exposure to stimuli prior to performing the task.
- While factors such as poor memory or vocabulary may have influenced a child's decision to request repetition, personality factors also played a role. Some children appeared reticent to request repetition, even when it was clear they were unsure of stimuli. The participants' level of confidence and their rapport with the tester also appeared to influence their decision to request repetition.
- Participants with SLI were hampered by their generally poor reading ability. In some instances their "speech errors" were clearly reading errors. For example, some participants produced the silent 'p' in "pneumonia".
- Participants with SLI were further hampered by their poor vocabulary knowledge. It was clear that they were unfamiliar with many of the words. As a result, as far as the participants were concerned, some items thus involved repetition of nonsense words, as they had never heard these words before. While the tester made some attempt to explain the meaning of the words, this task was still heavily reliant on working memory, and more so for participants with SLI than participants with typical development.

Conclusions: It is acknowledged that the fact that the Speech Assessment Battery is reliant on repetition, is a threat to the validity of the study. However, it is very difficult to elicit complex articulatory sequences from the age group in question using ecologically valid elicitation techniques. The naming/delayed imitation task used in this pre-test was influenced greatly by vocabulary, reading ability, and personality factors. Differences noted between the two groups could therefore not be attributed to differences in speech production per se. It was therefore decided to discontinue use of this task, as results were unreliable.

Appendix E: Oral Motor Evaluation (OME) Checklist.

(Score 0 if structure or function is within normal limits. Score 1 if there is a structural or functional abnormality.)

ASSESSMENT			SCORE			COMMENT
			S*	F*	SF	
LIPS	REST	1. Symmetry				
		2. Relationship (open vs closed)				
		3. Tone				
	ORAL FUNCTION	4. Round				
		5. Protrude				
		6. Retract				
		7. Alternate pucker/smile				
		8. Bite lower lip				
		9. Lip seal				
		10. Puff cheeks				
		11. Open-close lips				
	SPEECH FUNCTION	12. Rounding (o :)				
		13. Protrusion (u:)				
		14. Retraction /i:/				
		15. Alternate /u/ /i/				
		16. Bite lower lip (f)				
		17. Open/close lips /m /				
MAN-DIBLE	REST	18. Symmetry				
		19. Occlusion				
		20. Size (re:facial features)				
	ORAL FUNCTION	21. Excursion (click teeth 5x)				
		22. Diagonal movement				
		23. Dissociation mandible/tongue				
	SPEECH FUNCTION	24. During speech (excessive/fixed)				
MAXILLA	REST	25. Symmetry				
		26. Size				

TEETH	REST	27. Decay				
		28. Alignment				
		29. Gaps				
		30. Missing				
		31. Occlusion				
TONGUE	REST	32. Symmetry				
		33. Carriage				
		34. Cup-shape				
		35. Tone				
		36. Fasciculations				
		37. Furrowing				
		38. Size				
	ORAL FUNCTION	39. Protrusion				
		40. Elevation to alveolar ridge				
		41. Interdental (w/o assistance from teeth)				
		42. External elevation				
		43. External depression				
		44. External lateralisation				
		45. Slow circumoral				
	SPEECH FUNCTION	46. Elevation to alveolar ridge /n/ or /t/				
		47. Touch lateral edges of tongue to teeth “sh”				
		48. Interdental “th”				
		49. Posterior tongue to palate /k/				
		50. Coord with mandible “ng”				
		51. Vowel – high /i/				
		52. Vowel – mid /ɛ/				
		53. Vowel – low /æ/				
		54. Vowel – central				
		55. Diphthong /oj/				
		56. Dipthong /aj/				
PALATE		57. Structure				

VELOPHARYNX	REST	58. Symmetry				
		59. Uvula				
		60. Tonsils				
		61 Size of velum relative to pharyngeal cavity				
	SPEECH FUNCTION	62. /a:/				
		63. /ha:ha:ha:/				
RESPIRATION		64. Inspiration/expiration				
COORDINATED SPEECH MOVEMENTS		65. /p / repetitions				
		66. /t / repetitions				
		67. /k / repetitions				
		68. /p t k / repetitions				
		69. “buttercup” 1x				
		70. “buttercup” 2x				
		71. “buttercup” 4x				
		72. “buttercup” sustained repetition				
		73. “petticoat” 1x				
		74. “petticoat” 2x				
		75. “petticoat” 4x				
		76. “petticoat” sustained repetition				
PROSODY		77. Rate				
		78. Rhythm				
VOICE		79. Pitch				
		80. Loudness				
		81. Quality				
		82. Voice stoppages				
		83. Nasal resonance				
		84. Phonation duration /a:/				
		85. /s/ duration				
		86. /z/ duration				
		87. s:z ratio				

GENERAL	88. Posture				
	89. Tremor/tics				
	90. Face				
	91. Intelligibility				

Note: S= Structure; F= Function; SF = Speech Function

Appendix F: Administration and Scoring of the Oral Motor Evaluation (OME)

Instructions: *I need to look at your mouth to make sure all the parts required for speech are all right. I won't touch you. Please follow the instructions or imitate what I am doing.*
Materials/equipment: Stopwatch, torch, gloves.

Item	Description	Instruction	Observe the following
1	Lip symmetry	None	Note drooping, asymmetry of any kind
2	Lip relationship	None	Note whether lips are closed at rest.
3	Tone	None	Evidence of low or high tone ie flaccidity or spasticity.
4	Lip rounding	Round your lips like this (demonstrate)	Symmetry, ability to imitate
5	Lip protrusion	Stick out your lips as if you are going to kiss someone	Symmetry, ability to imitate
6	Lip retraction	Smile	Symmetry
7	Alternate pucker/smile	Blow a kiss and smile. Do it over and over until I tell you to stop.	Coordination of movement. Symmetry.
8	Bite lower lip	Bite your lower lip (demonstrate)	Observe occlusion
9	Lip seal	Blow up your cheeks. Now do it again but put your tongue between your lips	Do lips remain sealed?
10	Puff cheeks		Velopharyngeal closure
11	Open-close lips	Open and close your mouth like a fish (demonstrate)	Coordination of rapidly alternating movement.
12	Lip rounding (sp)	Say oa (as in boat)	Observe symmetry and coordination of movements. Listen for distortions.
13	Protrusion (sp)	Say ooh (as in two)	
14	Retraction (sp)	Say eee (as in bee)	
15	Alternate /u/ /i/	Say oo-ee	
16	Bite lower lip	Say /f/	
17	Open-close lips (sp)	Say mamamamama	
18	Symmetry of mandible at rest	None	Observe symmetry of mandible
19	Occlusion	None	Observe relationship of mandible and maxilla (eg underbite, overbite, crossbite)
20	Size	None	Is the mandible in proportion to other facial bones?
21	Excursion of teeth	Click teeth five times	Observe elevation and depression of mandible. Note range of movement, speed and accuracy.
22	Diagonal movement of mandible	Move your jaw down and sideways.	Note range and ease of movement
23	Dissociation of mandible /tongue	Stick your tongue between your teeth. Move your jaw sideways, but try to keep your tongue still.	Note whether jaw can move without excessive tongue movement.

24	Mandibular movement during speech	None – observe during other speech tasks.	Does mandible move excessively? Is it fixed?
25	Symmetry of maxilla	None	Is maxilla symmetrical?
26	Size of maxilla	None	Is maxilla in proportion to other facial bones? Is it depressed or protruding?
27	Teeth: decay	Open your mouth	Note discoloured teeth; halitosis
28	Teeth: alignment		Crooked teeth
29	Teeth: gaps		Widely spaced teeth (yet all present)
30	Teeth: missing		Gaps due to missing teeth
31	Teeth: occlusion		Ask participant to bite back teeth while lips are open. Observe relationship between upper and lower teeth.
32	Symmetry of tongue	Open your mouth wide so that I can see your tongue.	Is tongue symmetrical?
33	Carriage of tongue		Where is tongue at rest?
34	Cup-shape of tongue at rest		Does tongue have a cup-shaped appearance at rest? Make sure person is relaxing the tongue.
35	Tone of tongue		Flaccid or spastic?
36	Fasciculations		Involuntary movements of tongue muscles.
37	Furrowing of tongue		Deep grooves on surface of tongue.
38	Size		Size relative to oral cavity.
39	Tongue protrusion	Stick out your tongue	Symmetry; how far it protrudes
40	Elevation to alveolar ridge	Lift your tongue to your palate behind your teeth	Accuracy and symmetry of movement. Ability to imitate.
41	Interdental position of tongue	Put your tongue between your teeth without biting it.	Make sure the teeth are not quite touching the tongue. The participant should be able to keep their tongue in that position for a few seconds.
42	External elevation of tongue	Stick out your tongue and try to lick your nose.	Range and accuracy of movement.
43	External depression of tongue	Stick out your tongue and try to lick your chin	Range and accuracy of movement
44	External lateralization of tongue	Stick out your tongue and try to touch your ear. Now the other side.	Range, accuracy and symmetry of movement.
45	Slow circumoral movement	Lick around your lips slowly from top to bottom.	Look for jerkiness. Movements must be slow and steady.
46	Elevation to alveolar ridge (sp)	Say /n/	Listen and observe accuracy of movements.
47	Lateral edges of tongue to teeth	Say ‘sh’	
48	Interdental	Say ‘th’	
49	Posterior tongue to palate	Say ‘k’	
50	Coordination with mandible	Say ‘ng’	
51	High vowel	Say ee (tea)	
52	Mid vowel	Say e (bed)	
53	Low vowel	Say a (cat)	
54	Central vowel	Say /Ə/ (butt**er**)	

55	Diphthong	Say oy (boy)	
56	Diphthong	Say eye (I)	
57	Palatal structure	Open wide. (use torch)	Observe for high arch palate, grooves, evidence of clefts
58	Symmetry of velum		Does velum deviate to one side?
59	Uvula		Size and symmetry of uvula
60	Tonsils		Enlarged?
61	Size of velum relative to pharyngeal cavity?		Too short? Too long?
62	/a:/	Say ah (car)	Note hypo- or hypernasality
63	/ha:ha:ha:/	Say hahaha	Note hypo- or hypernasality.
64	Inspiration/expiration	None	Note throughout the assessment whether participant has adequate breath control eg shallow breaths, clavicular breathing.
65	/pe/ repetitions	Say /pepepe/ as many times as you can.	Compare to normative data.
66	/te/ repetitions	Say /tetete/ as many times as you can.	
67	/ke/ repetitions	Say /kekeke/ as many times as you can.	
68	/peteke/ repetitions	Say /peteke/ as many times as you can	
69	Buttercup 1x	Say the word 'buttercup' once	Note any sequencing errors.
70	Buttercup 2x	Now say it twice	
71	Buttercup 4x	Say it four times	
72	Buttercup sustained repetition	Say it as many times as you can	
73	Petticoat 1x	Say the word 'petticoat' once	
74	Petticoat 2x	Now say it twice	
75	Petticoat 4x	Say it four times	
76	Petticoat sustained repetition	Say it as many times as you can	
77	Rate	None	Make an overall subjective evaluation of the person's speaking rate. Too fast or too slow?
78	Rhythm	None	Is the rhythm or speech normal i.e. patterns of stress and intonation, pauses etc?
79	Pitch	None	Is voice too high or too low pitched for gender?
80	Loudness	None	Is voice too loud or soft for situation?
81	Quality	None	Note any unusual voice quality eg hoarseness, breathiness
82	Voice stoppages	None	Are there times when person has difficulty sustaining voicing?
83	Nasal resonance	None	Overall judgement of nasality.
84	Phonation duration /a/	Say /a:/ as long as you can. I am going to time you.	Time accurately. Compare to normative data.
85	/s/ duration	Say /s/ as long as you can. Take a deep breath first.	Time accurately. Compare to normative data.

86	/z/ duration	Say /z/ as long as you can. Take a deep breath first.	Time accurately. Compare to normative data.
87	s:z ratio	None	Calculate s:z ratio (duration of /s/ divided by duration of /z/). Compare to normative data.
88	Posture	None	Observe throughout the assessment. Does the person slouch/ have poor posture?
89	Tremor/tics	None	Observe throughout the assessment whether there are any tremors or tics.
90	Face	None	Observe for any dysmorphic features eg hypertelorism.
91	Intelligibility	None	Overall rating of intelligibility, based on conversation and performance on speech tasks.

Appendix G: The Speech Assessment Battery

Multisyllabic Word List (Catts, 1986)

Instructions: *I am going to say some words to you. I want you to repeat the word after me. I can only say the word once, so listen carefully. Let's do one for practice.* ***Example:*** *encyclopaedia.*

1. peculiar
2. aluminium
3. emphasis
4. probably
5. cinnamon
6. associate
7. vacancy
8. establish
9. parallel
10. synthesis
11. calendar
12. susceptible
13. consciousness
14. orchestra
15. vulnerable
16. mobilize
17. symphony
18. regularly
19. exclamation
20. statistics
21. syllable
22. philosophy
23. animal
24. substantial
25. sympathise
26. specific
27. enemy
28. municipal
29. catalogue
30. suspicious
31. terminal
32. skeptical
33. fire extinguisher
34. hemisphere
35. permanent
36. consequence
37. particularly
38. statistician
39. pneumonia
40. physicist
41. navigator
42. especially
43. chivalry
44. enthusiasm
45. specify

Nonsense Word Repetition (Kamhi & Catts, 1986)

Instructions: *I am going to say some words to you. These are not real words, they are made up or nonsense words. I want you to repeat the word after me. I can only say the word once, so listen carefully.*

1. bǽθərɪs
2. rəbésɪt
*3. tríbəbɪl
4. pəˠsíkəlʌmɪ
*5. səʃáfəsɪ
6. pɛθətol
*7. səsítəbɪ
8. tʃəlátɪs
*9. sənúmənən
*10. spəpístɪks
11. ʃəbáfədɪ
*12. spéθəstoup
13. mákəvən
*14. brəbéskɪt
15. sənákəvən
16. dəsípələ
17. bəkátəpɪ
*18. tʃəfástɪtʃ
19. səkísɪp
*20. stəsǽfɪk
21. rǽbəlɪ
*22. vəsíʃəs
*23. gədǽkɪk
24. səkǽvɪt
25. wətáfədɪ
*26. fǽθəsɪs
*27. dəˠplíkjələˠlɪ
28. dəsíbəs
29. kəsǽbəs
*30. mánəmən

* Difficult to articulate

Phrase Repetition (Catts, 1987 in Lewis & Freebairn, 1992)
Instructions: *I am going to say some phrases to you. I want you to repeat the phrase after me. I can only say the phrase once, so please listen carefully. Let's try one for practice.* ***Example:*** *Sea gulls.*

1. Tow boat.
2. Toy boat.
3. Three small crabs.
4. Quiet crabs claw.
5. Cheap car.
6. Blue brush.
7. He sews.
8. Quite right.
9. Snow slope.
10. Weak smile.
11. Black broom.
12. Snow fence.
13. Blue star.
14. She sews.
15. Just right.
16. Sea shells.
17. Tom wears shoes.
18. Big black bread.
19. Small wrist band.
20. She sells shirts.
21. Nine horse flies.
22. Mixed biscuits.
23. Bright blue beam.
24. He makes shirts.
25. Big farm house.
26. Fine fruit flies.
27. Blue plaid pants.
28. Waste baskets.
29. Sam shines shoes.
30. Brand new pants.
31. Swiss wristwatch
32. Dark blue hat.
33. Cheap shot.
34. Weak wrist.
35. Small broom.

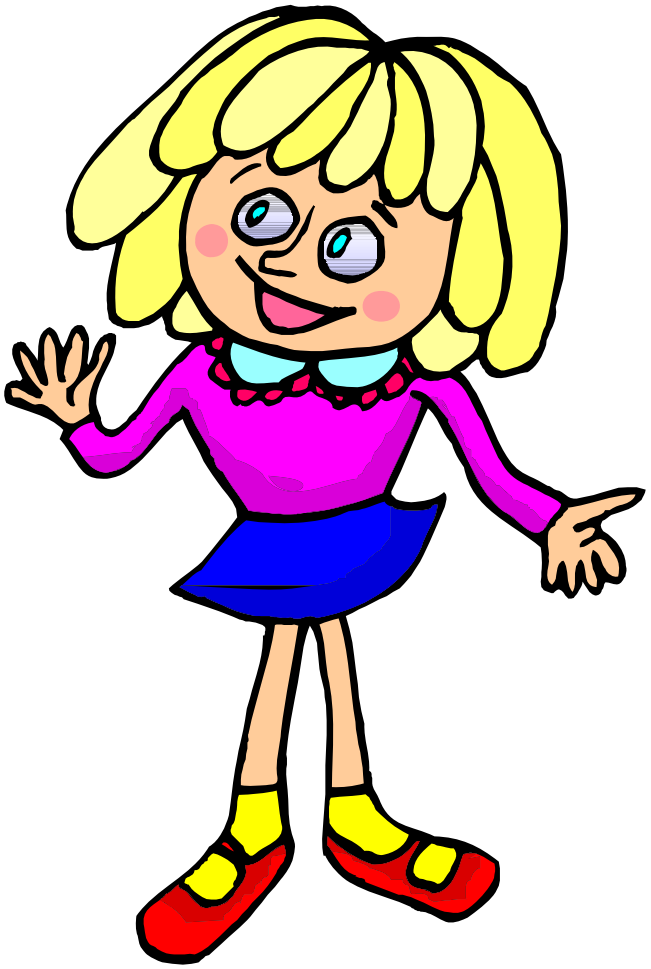
Sentence Repetition (Kamhi & Catts, 1986)
Instructions: *I am going to say some sentences to you. I want you to repeat the sentence after me. I can only say the sentence once, so please listen carefully. Try to say the sentence exactly like I said it.*

1. Have some fried flounders.
2. The spy fled to Greece.
3. He likes split pea soup.
4. Big black bug's blood.
5. Six slim sailors.
6. Brown and blue plaid pants.
7. Wash each dish twice.
8. Shiny seashell necklace.
9. Tom threw Tim three thumbtacks.
10. Sheep should sleep in a shed.

Tongue Twisters (administered with picture stimuli).
Instructions: *I am going to show you some sentences. I will read each sentence to you once. Then I want you to say the sentence once. As soon as you feel you can remember the sentence, you will say it five times, while I time how long it takes you. Don't worry about counting the sentences, as I will tell you when to stop. Let's try one for practice.* ***Example:*** *A big black bug bit a big black dog on his big black nose.*

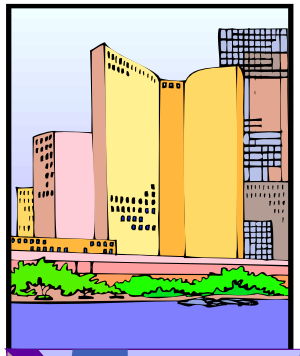
1. She sees cheese.
2. Six shining cities.
3. Red lorry, yellow lorry.
4. He threw three balls.
5. Santa's short suit shrunk.
6. Green glass globes glow greenly.
7. Which witches wished wicked wishes?
8. Which wristwatch is a Swiss wristwatch?
9. Barbara burned the brown bread badly.
10. She sells seashells by the seashore.

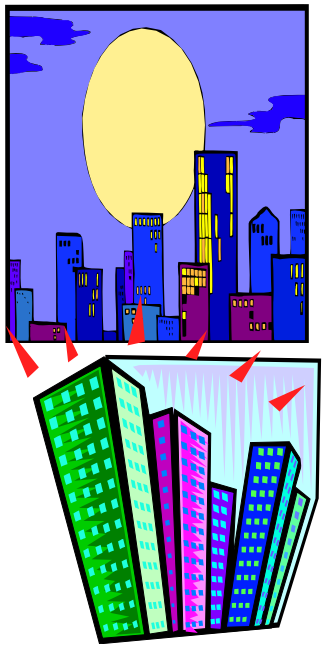




She sees cheese.



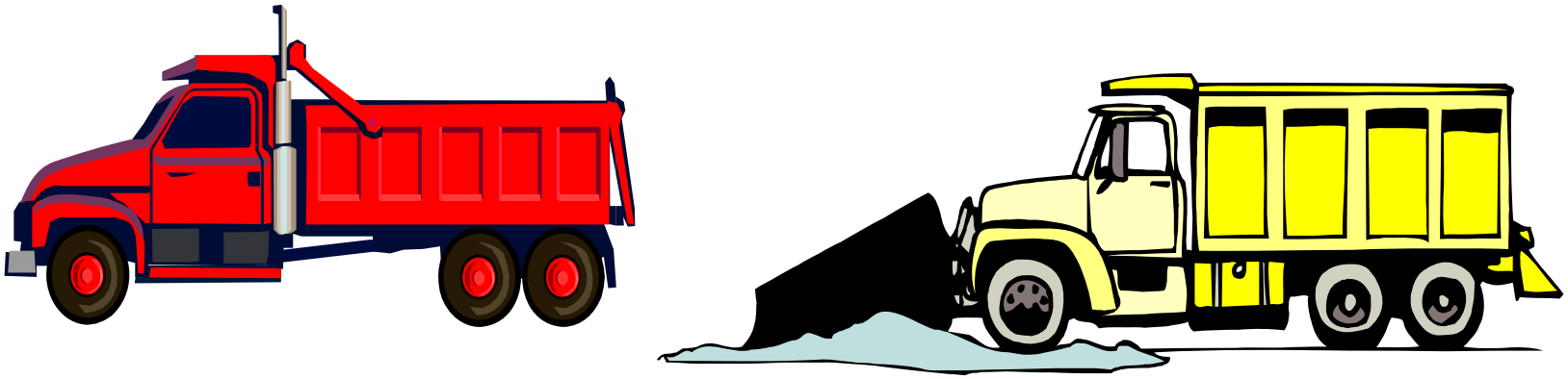




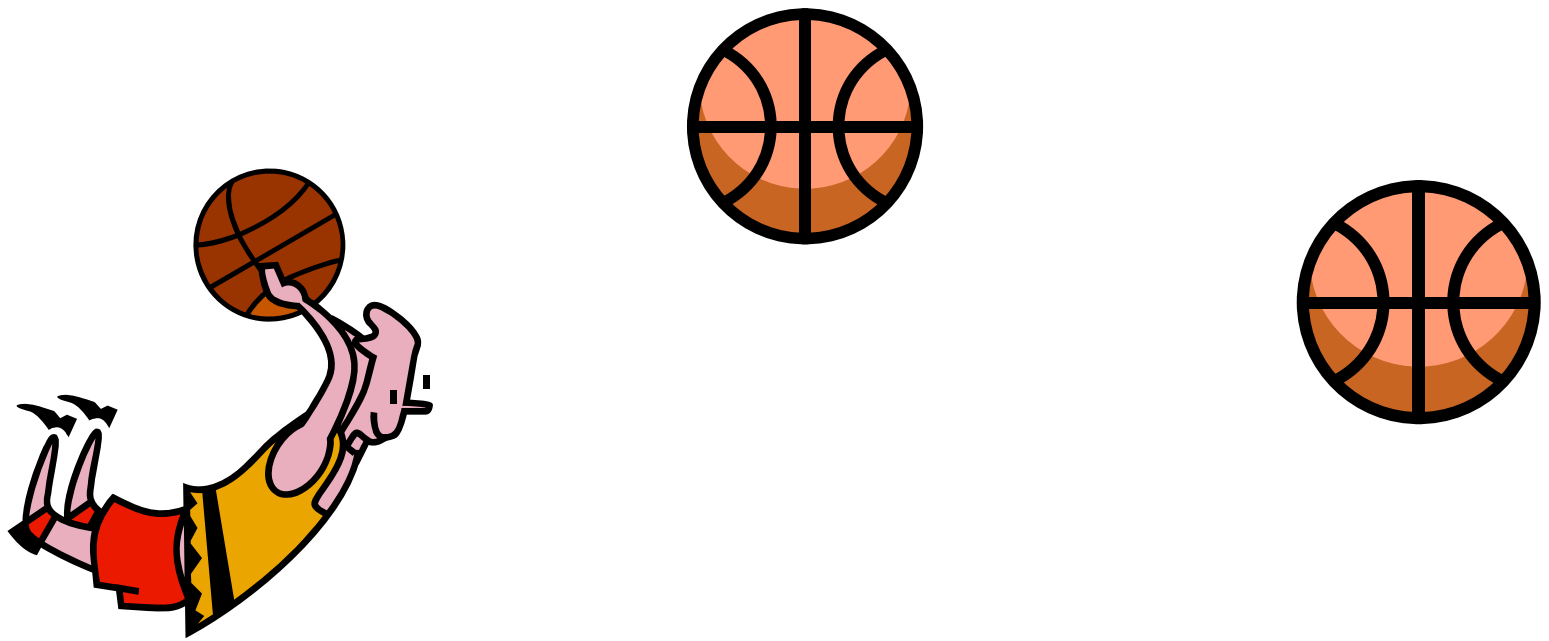




6 shining cities.



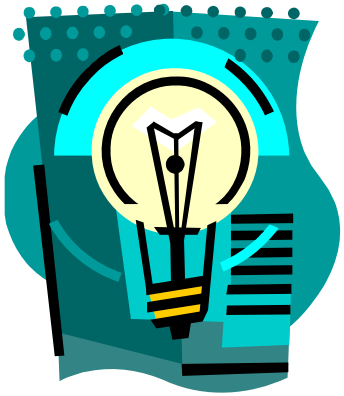
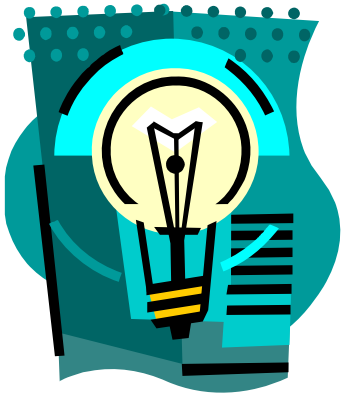
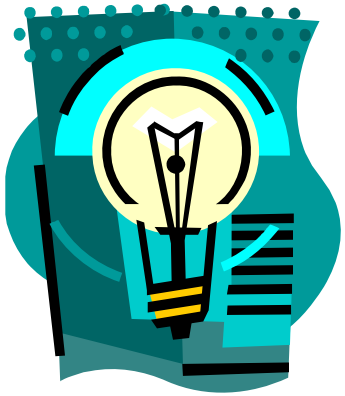
Red lorry, yellow lorry.



He threw 3 balls.

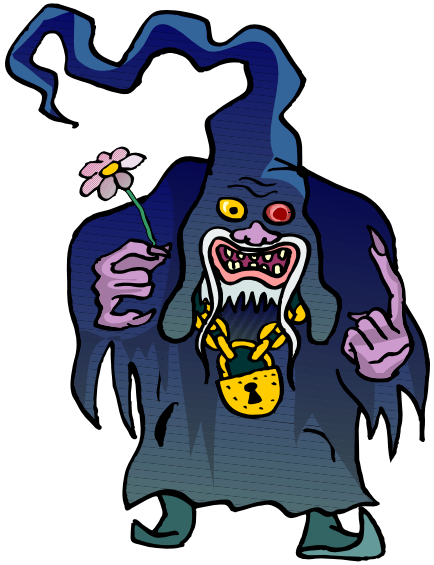


Santa’s short suit shrunk.

Green glass globes glow greenly.



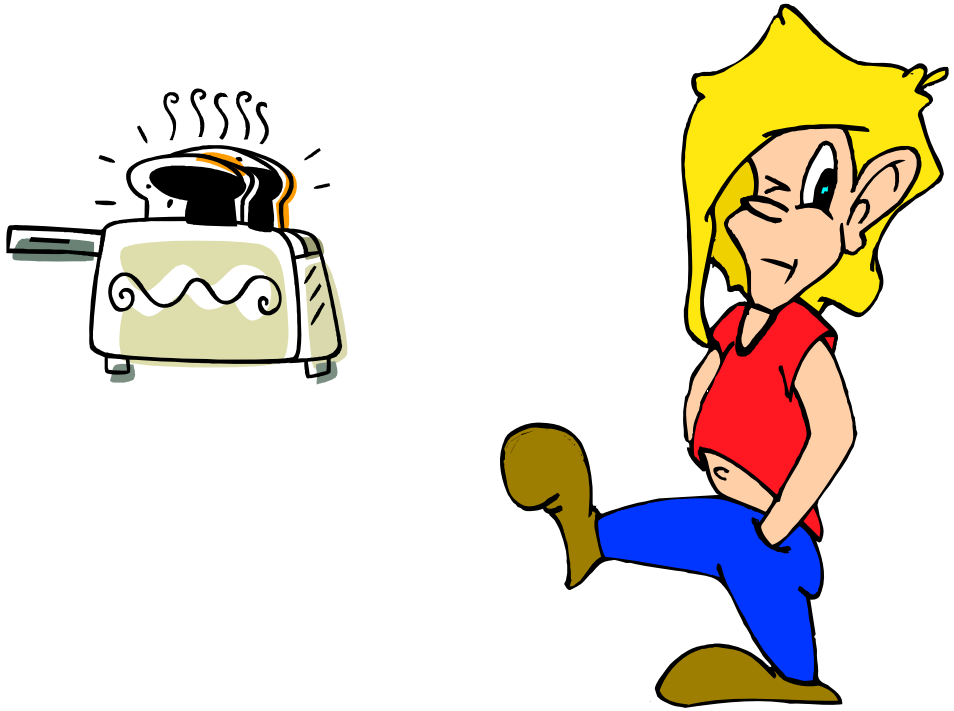




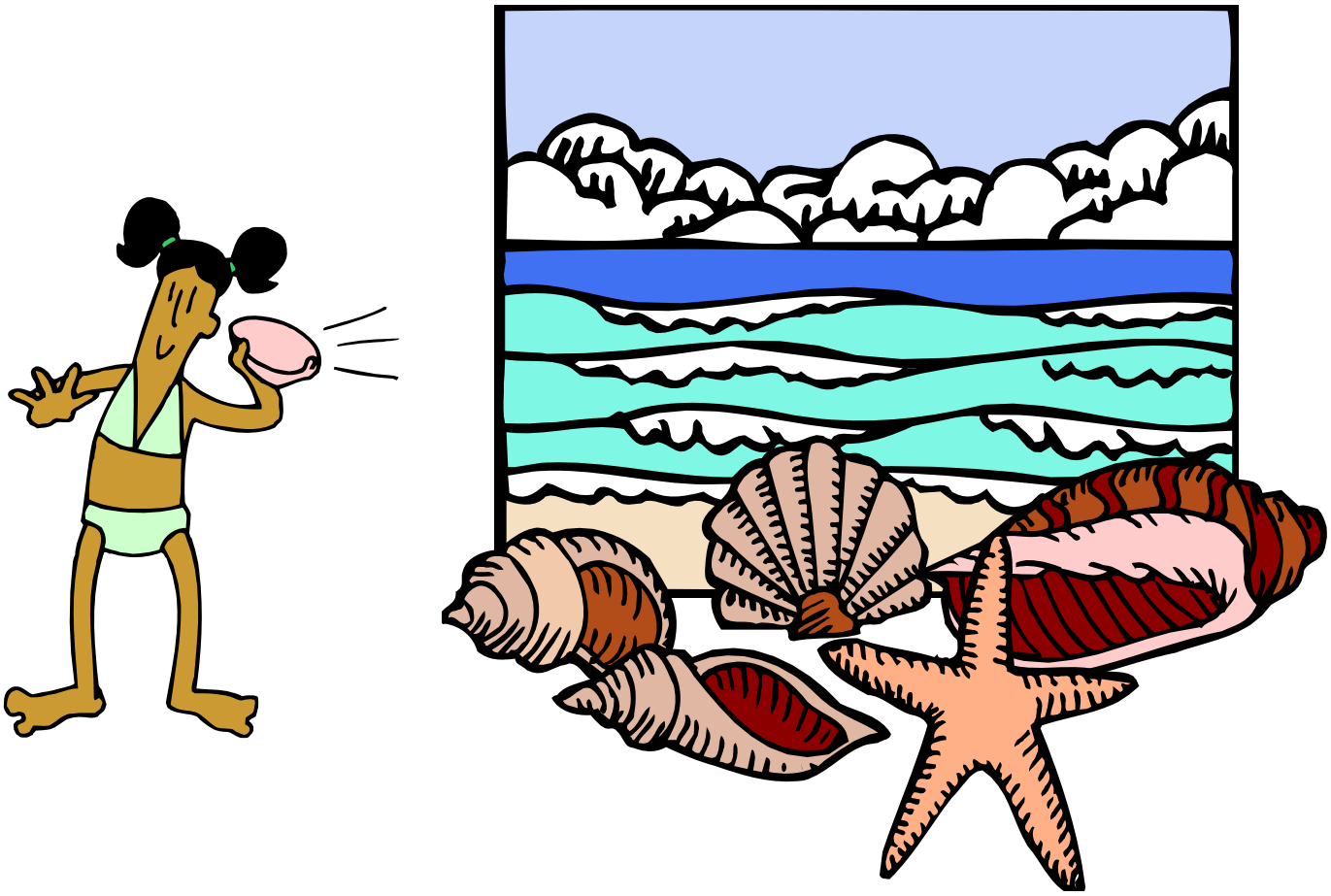
Which witches wished wicked wishes?



Which wristwatch is a Swiss wristwatch?



Barbara burned the brown bread badly.



She sells seashells by the seashore.

Appendix H: Children's Test of Nonword Repetition

(Gathercole & Baddeley, 1996)

perplisteronk
loddernapish
woogalamic
blonterstaping
skiticult
tafflest
frescovent
bannow
detratapillic
contramponist
brasterer
empliforvent
underbrantuand
diller
glistow
pristoractional
ballop
penerriful
reutterpation
altupatory
hampent
sladding
bannifer
versatrationist
barrazon
commerine
doppelate
glistering
fennerizer
voltularity
thickery
commeecitate
sepretennial
confrantually
pennel
trumpetine
stopograttic
rubid
prindle
defermication

Appendix I: Categories and Criteria Used to Analyse the Risk Factor Questionnaire.

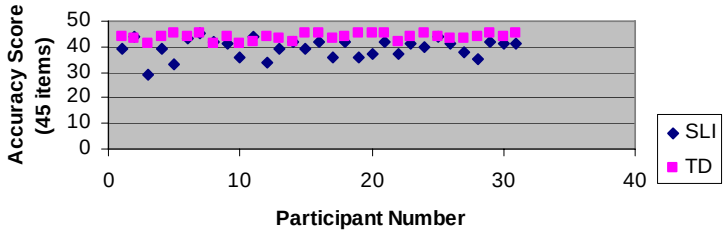
Category		Judgement	Criteria
Early History		Significant	Any pre-, peri- or post-natal complications. Delayed motor or speech milestones.
		Not significant	No pre-, peri- or post-natal complications. Motor and speech milestones within normal limits, or not reported.
Otitis media/ Hearing		Present	Any history of otitis media or grommets.
		Absent	No history of otitis media.
Attention Deficit (Hyperactivity) Disorder		Present	Diagnosed by a medical professional or psychologist.
		Absent	No report of AD(H)D.
Family History	**Phonological Disorder**	Yes	Family history of speech difficulties, described as difficulty in producing specific sounds.
		No	No reported history.
	Language Disorder	Yes	Family history of delayed language and/or speech therapy for language difficulties.
		No	No reported history.
	Learning Difficulties	Yes	Family history of reading, writing or mathematical difficulties, and/or a history of placement in a school for learners with special needs, and/or a history of remedial or speech-language therapy for educational difficulties.
		No	No reported history.
Speech Development		Phonological disorder	Difficulty in saying specific sounds and/or delayed acquisition of sounds, and/or unintelligible to people outside the family beyond age 4 years, and/or identified as having speech errors by preschool teacher, and/or history of speech therapy for phonological disorder, and/or current speech errors or difficulty in producing long words.
		Normal speech development	Age appropriate speech errors.
		Cannot be determined	Speech development not reported or not recalled.
Motor Development		Motor deficits	Difficulty with gross or fine motor tasks, and/or occupational therapy for muscle tone or motor deficits.
		Normal motor development	No reported difficulty with motor tasks.
		Cannot be determined	Motor development not reported or not recalled.

Appendix J: Categories and Definitions Used to Analyse the Speech Assessment Battery.

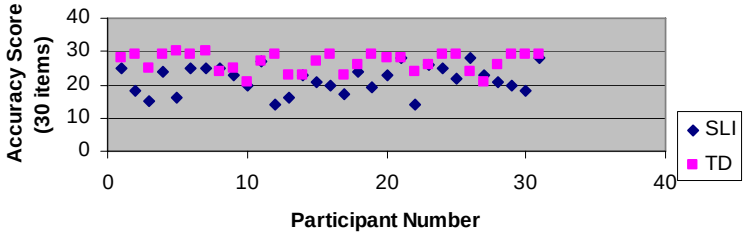
Category		Definition
Changes to syllable structure	*Addition*	Addition of a phoneme or syllable to the target word.
	Sound omission	Omission of one or more phonemes from the same locus of the target utterance. This includes weak syllable deletion and cluster reduction.
Sound substitution errors	*Assimilation*	A substitution error where the error phoneme was influenced by place or manner of production of other phonemes in the target utterance, even if these phonemes are not in the same word.
	Transposition	Two phonemes within the same word are exchanged. Both phonemes must still be present in the word.
	Sound substitution	One standard phoneme of English is substituted for another phoneme. This category excludes transposition or assimilation errors.
	Word substitution: phonemic	A word in the target phrase or sentence is substituted with another recognizable English word. The substitution is phonologically based, i.e. it is the result of an addition, omission or phoneme substitution error.
Fluency errors	*Prolongation*	Production of a phoneme is prolonged sufficiently to draw attention to itself.
	Hesitation	A pause between words which is sufficiently long to draw attention to itself.
	Interjection	The addition of phonemic segments between words, for example, *um, er*. Interjections may consist of words or part-words which are not part of the intended message and which do not carry meaning.
Repetitions/ Revisions	*Sound/part-word repetition*	Repetition of one or more phonemes which do not form a completed word. Each repetition of a sound or part-word is counted separately. The repetition may contain additional errors, such as syllable structure or substitution errors.
	Word repetition	A word is repeated within a target phrase or sentence. This word may contain additional errors. This includes any repetition of a word within a compound word, such as "wristwatch" or "seashore".
	Phrase repetition	Repetition of more than one word within a target phrase or sentence. These words may contain additional errors.
	Revisions	Repetition of a part-word, word, or phrase, which does not match the first attempt at the utterance.
Sentence-level errors	*Word omission*	Omission of a word in a target phrase or sentence.
	Word substitution: semantic	A word in the target phrase or sentence is substituted with another recognizable English word. The substitution is based on meaning, rather than phonological structure. For example, substituting the preposition "at" for "by"; or the noun "fly" for "bug".
	Word addition	Addition of a word not in the target utterance.
Distortion		Substitution of a non-standard English phoneme for a standard phoneme.
No Response		Any refusal to complete the item or a request for repetition.
Other		Any deviations from the model provided, which are not described by the above categories.

Appendix K: Scattergrams of Individual Scores on the Speech Assessment Battery

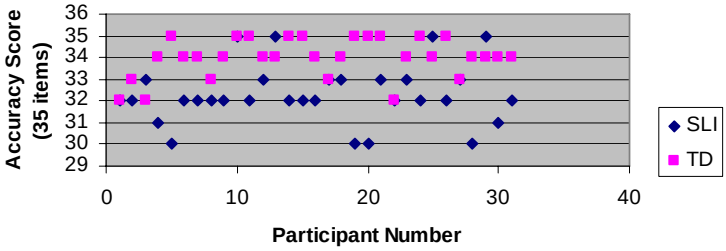
K1: Accuracy Scores



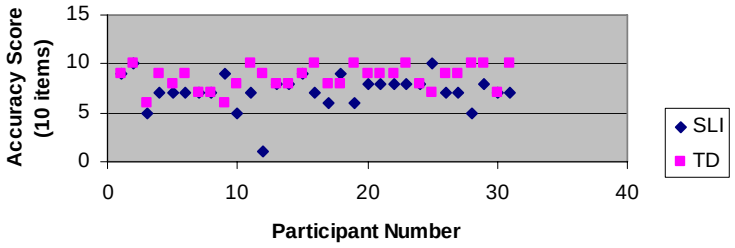
(a) Multisyllabic Word List



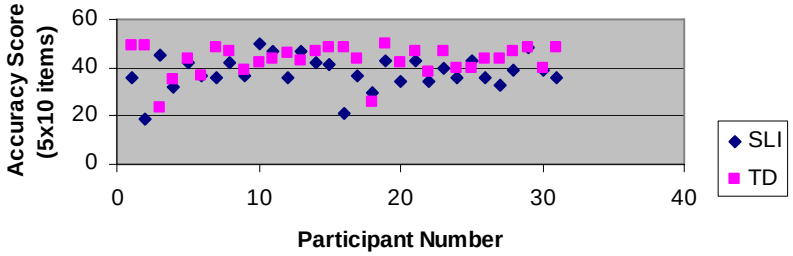
(b) Nonsense Word Repetition



(c) Phrase Repetition



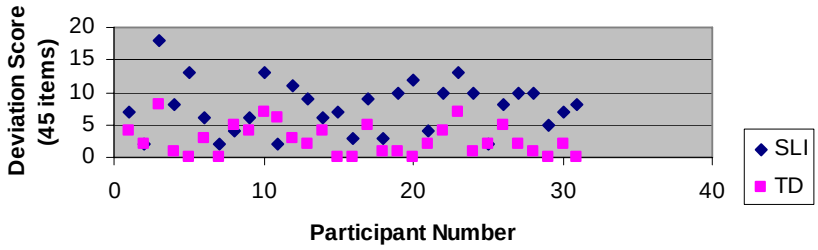
(d) Sentence Repetition



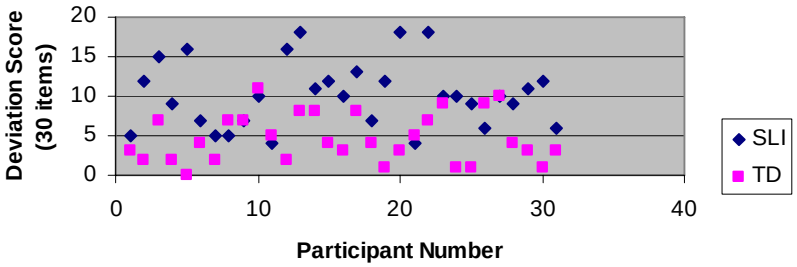
(e) Tongue Twister Task

Figure K1a-e: Comparison of individual Accuracy scores

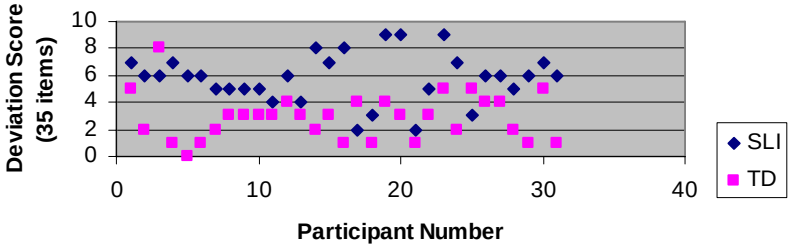
K2: Deviation Scores



(a) Multisyllabic Word List



(b) Nonsense Word Repetition



(c) Phrase Repetition

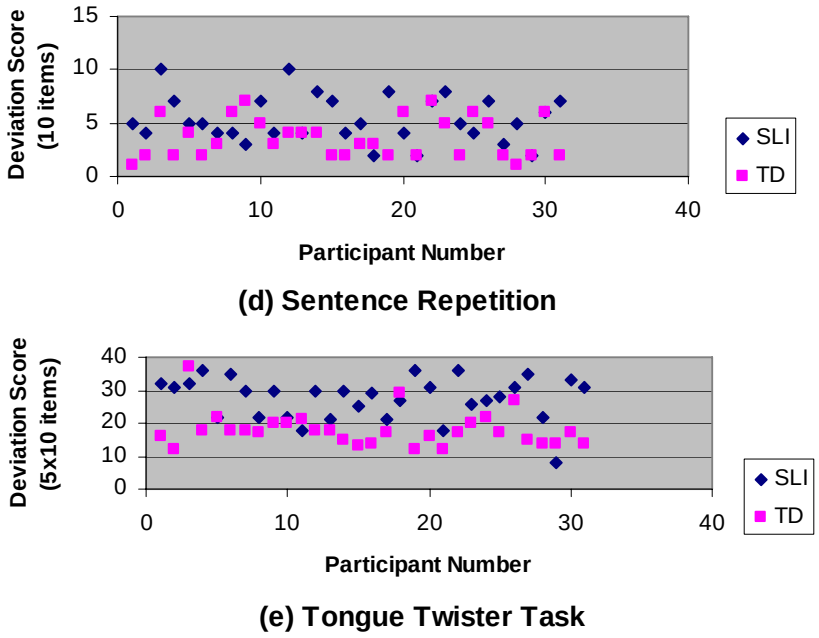
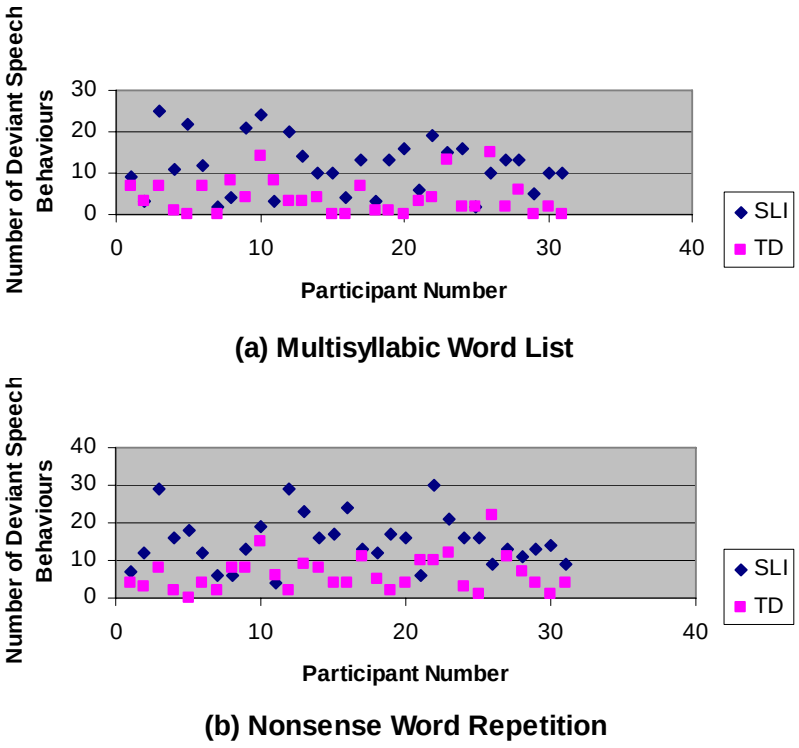
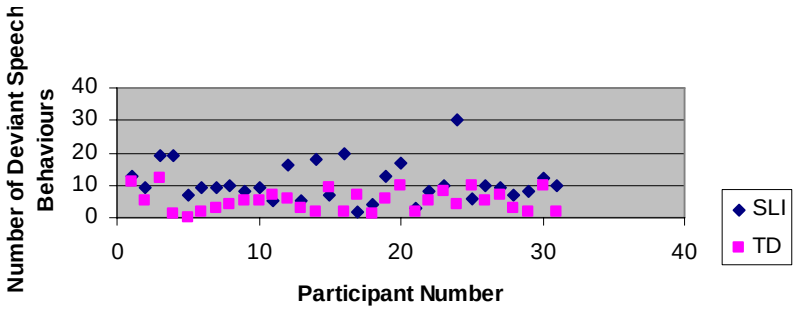


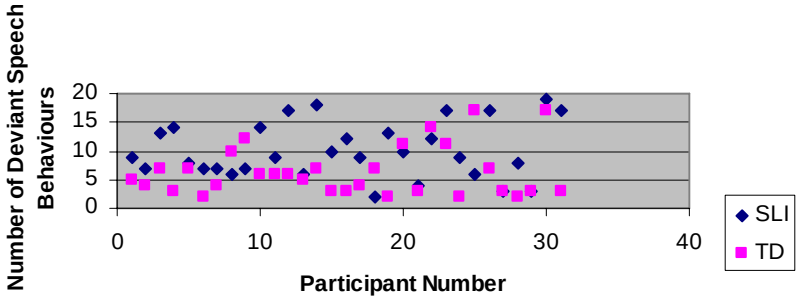
Figure K2a-e: Comparison of individual Deviation scores.

K3: Number of Deviant Speech Behaviours Scores

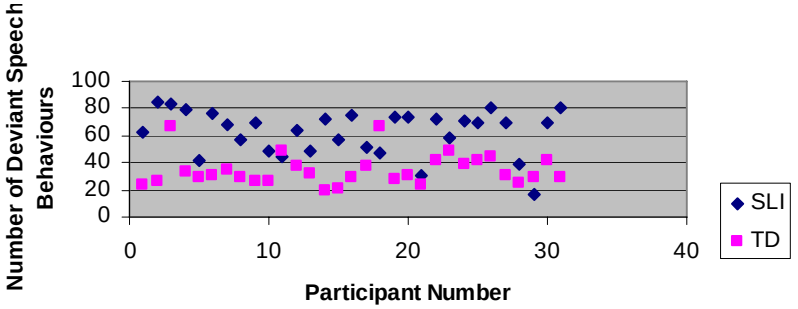




(c) Phrase Repetition



(d) Sentence Repetition



(e) Tongue Twister Task

Figure K3a-e: Comparison of individual Number of Deviant Speech Behaviours scores.

Appendix L: Comparison of TD Group, Typically Developing Late Adolescents and Young Adults.

Table L1. Comparison of mean Deviation scores obtained by TD group, typically developing late adolescents and young adults on the Speech Assessment Battery.

	TD Group (current study)	Late Adolescents (Philippou, 2005; Signer, 2005)	Young Adults (Alston, 2005; Karodia, 2005)
Description of Participants	n=31 Mean age=13y4m	n=38 Mean age=18y2m	n=40 Mean age=24y11m
Multisyllabic Word List (45 items)	2.65	0.87	0.85
Nonsense Word Repetition (30 items)	4.65	3.11	2.88
Phrase Repetition (35 items)	2.87	2.63	1.63
Sentence Repetition (10 items)	3.58	3.00	2.15
Tongue Twisters (50 items)	18.06	13.21	9.28

Table L2. Comparison of mean Number of Deviant Speech Behaviours obtained by TD groups, typically developing late adolescents and young adults on the Speech Assessment Battery.

	TD Group (current study)	Late Adolescents (Philippou, 2005; Signer, 2005)	Young Adults (Alston, 2005; Karodia, 2005)
Description of Participants	n=31 Mean age=13y4m	n=38 Mean age=18y2m	n=40 Mean age=24y11m
Multisyllabic Word List (45 items)	4.10	1.02	1
Nonsense Word Repetition (30 items)	6.26	3.61	3.5
Phrase Repetition (35 items)	5.13	3.97	2.45
Sentence Repetition (10 items)	6.32	4.66	3.625
Tongue Twister (50 items)	34.52	20.92	14.95

Appendix M: Additional Data Related to Tongue Twister Time Scores

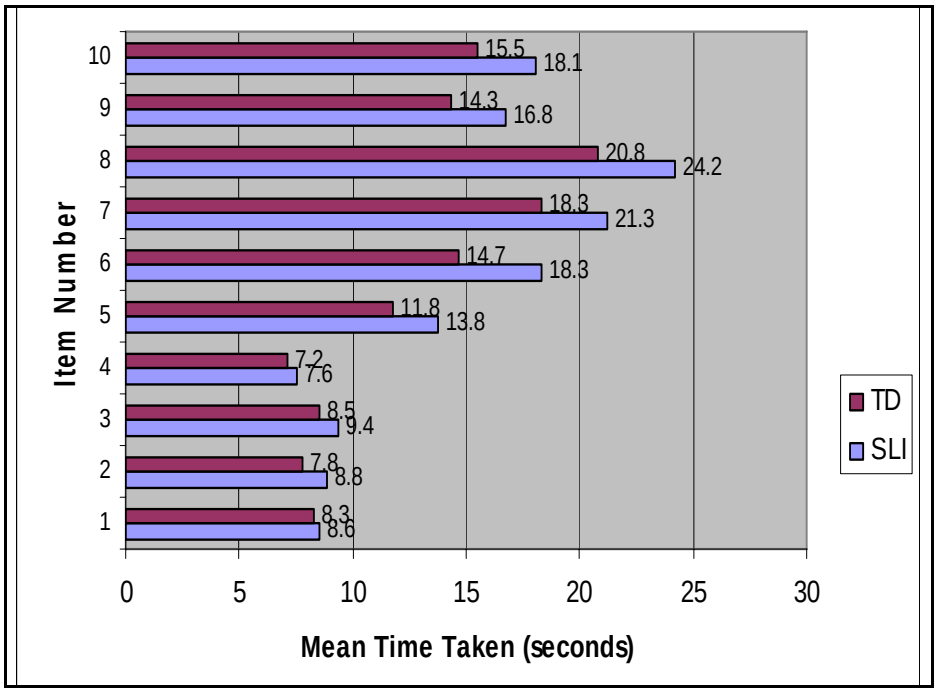


Figure M1: Comparison of mean time taken per item on Tongue Twister task.

Table M1: Correlation between total time on Tongue Twisters and measures on the Speech Assessment Battery for the SLI and TD groups.

TASK	MEASURE	SLI	TD
Multisyllabic Word List	Accuracy	-0.28276 (p=0.1232)	0.36545 (p=0.0432)*
	Deviations	0.28508 (p=0.1201)	0.40359 (p=0.0233)*
	Number of Deviant Speech Behaviours	0.20824 (p=0.2609)	0.32307 (p=0.0763)
	Attempts	0.20760 (p=0.2624)	0.17481 (p=0.3469
Nonsense Word Repetition	Accuracy	-0.00202 (p=0.9914)	-0.30877 (p=0.0910)
	Deviations	0.01094 (p=0.9534)	0.36291 (p=0.0448)*
	Number of Deviant Speech Behaviours	0.07551 (p=0.6864)	0.30347 (p=0.0970)
	Attempts	0.17658 (p=0.3420)	-0.02683 (p=0.8861)
Phrase Repetition	Accuracy	-0.20762 (p=0.2624)	-0.09823 (p=0.5991)
	Deviations	0.30795 (p=0.0919)	0.34169 (p=0.0599)
	Number of Deviant Speech Behaviours	0.42454 (p=0.0173)*	0.32529 (p=0.0742)
	Attempts	0.29116 (p=0.1120)	0.19265 (p=0.2991)
Sentence Repetition	Accuracy	-0.37917 (p=0.0354)*	-0.24899 (p=0.1768)
	Deviations	0.60771 (p=0.0003)***	0.41512 (p=0.0202)*
	Number of Deviant Speech Behaviours	0.40081 (p=0.0254)*	0.42616 (p=0.0168)*
	Attempts	0.28896 (p=0.1149)	0.16299 (p=0.3810)
Tongue Twisters	Accuracy	0.06261 (p=0.7379)	-0.01137 (p=0.9516)
	Deviations	0.47647 (p=0.0067)**	0.13044 (p=0.4843)
	Number of Deviant Speech Behaviours	0.49884 (p=0.0043)**	0.21261 (p=0.2508)
	Attempts	0.60610 (p=0.0003)***	0.10732 (p=0.5656)
OME	Structure	0.15233 (p=0.4133)	0.52487 (p=0.0024)**
	Function	0.31169 (p=0.0878)	0.19593 (p=0.2908)
	Speech Function	-0.03183 (p=0.8650)	0.00312 (p=0.9867)

Key: *$*p<0.05$; $**p<0.01$; $***p<0.001$*

Appendix N: Description of SLI Participants' Language Scores

In Table N1 below, the scores obtained by all the SLI participants on the language test battery are presented. Expressive syntax (Formulated Sentences) was an area of deficit for the majority (80.6%) of the participants with SLI. This result is in agreement with the literature regarding SLI, which identifies impairments of morphosyntax as one of the key characteristics of children with SLI. Ambiguities was a second area of deficit for the majority (71%) of the participants. This task is demanding of the receptive and expressive abilities of adolescents, and appears to be sensitive to the deficits experienced by this group. Approximately a third (35.5%) of the group performed poorly on the narrative task, again indicating their language breakdown on a demanding task. This finding is also consistent with the literature regarding SLI, which reports that narratives are particularly difficult for children with SLI (Miranda, McCabe & Bliss, 1998; Kaderavek & Sulzby, 2000). A substantial number of participants (19%) still present with phonological processing difficulties as measured on the Spoonerisms task. Few participants obtained low scores on the two TOAL-2 subtests, LV (19%) and LG (22%). This finding can be ascribed to one of three reasons. Firstly, the tests may not have been sensitive enough to impairments in this group. Secondly, as the majority of participants had attended speech-language intervention, it is possible that they may have had weaknesses in receptive syntax and vocabulary at some point, but have improved after intervention. Thirdly, sampling error may have resulted in a group with primarily expressive syntax deficits, although it is felt that the first two explanations are more likely. Similarly, not many participants (12.9% or n=4) obtained poor scores on the Word Associations task. It was apparent that participants found this task very easy, and it is likely that this task was not sufficiently sensitive to expressive semantics or word-finding difficulties in this group of participants.

Overall, the language deficits exhibited by this group of SLI participants are, perhaps, not as extensive as was expected. However, it should be remembered that they were recruited, in part, on the basis of clinical diagnosis. It is well-established that there is sometimes lack of congruence between clinical

and research identification of SLI, in part, because standardized language measures are not always sensitive to the type of language difficulties experienced by children with SLI (Aram, Morris & Hall, 1993; Dunn, Flax, Sliwinski & Aram, 1996).

Table N1: Language test scores for SLI participants.

	TOAL-2		TLC	CELF-R		PhAB	Narrative
	LV	LG	Ambig.	FS	WA	Sp	
S1	8	10	6	8	12	110	18
S2	8	9	7	6	14	76	18
S3	7	7	3	4	12	86	20
S4	9	11	8	3	7	90	9
S5	6	8	6	3	9	85	15
S6	8	9	7	5	10	89	12
S7	12	11	6	6	8	82	15
S8	11	11	13	6	12	91	9
S9	7	12	9	11	16	101	14
S10	11	11	10	5	14	97	23
S11	9	11	10	7	9	95	12
S12	9	9	8	3	10	88	19
S13	8	12	8	6	10	97	12
S14	8	9	6	3	9	90	13
S15	11	7	7	6	14	90	19
S16	11	11	6	5	15	90	26
S17	10	8	6	6	10	82	23
S18	9	11	8	8	11	90	31
S19	7	8	5	3	8	90	20
S20	6	12	4	5	10	102	10
S21	11	7	7	9	10	91	10
S22	11	11	6	5	9	88	13
S23	11	9	11	9	12	88	14
S24	8	11	7	6	9	86	20
S25	11	7	7	10	8	88	19
S26	6	6	5	5	7	81	8
S27	8	10	7	4	15	69	14
S28	8	7	4	3	6	88	19
S29	10	12	7	6	15	94	28
S30	9	11	7	4	10	90	19
S31	6	6	5	5	7	81	8
MEAN	**8.84**	**9.48**	**6.97**	**5.65**	**10.58**	**89.19**	**16.45**
SD	**1.81**	**1.93**	**2.09**	**2.14**	**2.74**	**7.73**	**5.89**
RANGE	**6-12**	**6-12**	**3-13**	**3-11**	**6-16**	**69-110**	**8-31**

-1SD and <-1SD **Key:** *LV=Listening Vocabulary LG=Listening Grammar Ambig=Ambiguities FS=Formulated Sentences WA=Word Associations Sp=Spoonerisms*

Note: TOAL-2, TLC and CELF-R scores refer to scaled scores with a mean of 10 (*SD*=3). Spoonerisms scores refer to a standard score with a mean of 100 (*SD*=15). The Narrative Quality score has a maximum raw score of 36. TD participants obtained a mean narrative score of 18.42 (*SD* 5.04).

Appendix O: SLI and TD Participants' Individual Results on Memory Tasks.

Table O1: SLI participants' scores on memory tasks

	CAS				PhAB	NWRep
	WS	SR	SQ	Quotient	PN	
S1	11	9	12	104	82	35
S2	4	7	8	77	90	35
S3	1	3	3	53	89	32
S4	7	7	8	84	75	39
S5	3	5	4	63	82	31
S6	10	7	5	84	73	35
S7	10	10	6	92	83	40
S8	9	10	6	90	69	38
S9	14	11	11	112	100	25
S10	10	10	6	92	97	32
S11	11	10	9	100	122	39
S12	8	7	1	71	90	27
S13	10	7	7	88	103	32
S14	8	6	6	79	97	35
S15	8	7	3	75	88	33
S16	9	10	5	88	92	38
S17	7	7	6	79	82	32
S18	15	13	10	115	101	37
S19	8	5	6	77	105	34
S20	11	9	7	94	109	36
S21	11	11	8	100	88	39
S22	12	8	7	94	85	28
S23	10	7	8	90	97	36
S24	14	11	13	115	99	39
S25	12	12	11	110	88	38
S26	12	11	7	100	84	30
S27	12	11	12	110	94	38
S28	12	3	9	88	99	31
S29	8	7	10	90	101	36
S30	11	8	6	90	92	37
S31	12	11	7	100	84	30
Mean	**9.68**	**8.39**	**7.32**	**90.45**	**91.61**	**34.42**
SD	**3.10**	**2.54**	**2.81**	**14.73**	**11.07**	**3.92**
Range	**1-15**	**3-13**	**1-13**	**53-115**	**69-122**	**25-40**

-1SD and <-1SD

Key:
WS=Word Series
SR= Sentence Repetition
SQ=Sentence Questions
PN=Picture Naming
NWRep=Nonword Repetition

Note: Subtest scores on the CAS relate to a mean of 10 (*SD* 3), while the CAS Quotient and PhAB PN scores relate to a mean of 100 (*SD* 15). The NWRep raw scores have a maximum of 40. The mean NWRep score of TD participants was 38.61 (*SD* 1.09).

Table O1 presents the scores for memory tasks for the participants with SLI. From Table O1 the following is apparent:

On the CAS subtests scores deteriorated as the working memory demands and processing demands increased. On a serial memory task (WS), only 16% of SLI participants obtained low scores. This number increased markedly on the sentence memory task (SR), where 45% of SLI participants had low scores, and even more so on the verbal working memory task (SQ), where 58% of participants obtained low scores.

One third (32.26%) of SLI participants had a below average successive processing quotient on the CAS, which is consistent with Naglieri's (1999) view that successive processing is required for syntactical processing. The majority of the SLI participants obtained low scores on a measure of expressive syntax.

Only 29% of SLI participants had low scores on the Picture Naming task, with most of these scores being over 80. Only three participants had markedly poor scores on this task. This result may be an artifact of the test's construction. Although the PhAB was developed for children up to the age of 14 years 11 months, there is much less variability in the scores reported for children over the age of 13 years (Frederickson, Frith and Reason (1997), which suggests that this test is less sensitive to differences in performance in older children.

On the nonword repetition task, the majority (70.9%) of SLI participants obtained scores that were 1*SD* or more than 1*SD* below the mean of the TD group.

Overall, Table O1 indicates that the SLI group presented with a markedly poor performance on memory tasks. This result was expected, in view of the large body of literature reporting memory deficits as a characteristic of SLI. It should be noted, however, that five participants (S11, S21, S24, S25 and S27) did not obtain low scores on any of the memory tasks. All five these participants obtained low scores on language tasks, indicating that they are language impaired, despite their apparently adequate memory abilities. These results would once again point to the heterogeneity within the SLI population, where a single explanation, such as an underlying memory deficit, will not account for the language deficits seen in all children with SLI.

Table O2 summarises the performance of TD participants on memory tasks.

Table O2: TD participants' scores on memory tasks

	CAS				PhAB	
	WS	**SR**	**SQ**	**Quotient**	**PN**	**NWRep**
N1	11	13	10	108	131	38
N2	14	15	14	125	121	38
N3	14	10	8	104	103	38
N4	11	12	9	104	94	40
N5	15	10	6	102	90	40
N6	11	10	8	98	97	38
N7	10	7	9	92	84	38
N8	9	7	7	86	80	38
N9	12	10	6	96	95	38
N10	12	11	6	98	88	35
N11	12	10	8	100	93	38
N12	12	12	8	104	101	40
N13	3	5	5	65	95	37
N14	12	11	10	106	90	37
N15	13	12	10	110	88	39
N16	16	13	14	125	112	39
N17	11	13	11	110	105	38
N18	13	10	11	108	103	39
N19	16	13	11	119	129	40
N20	18	14	11	125	82	39
N21	11	12	10	106	93	40
N22	10	8	4	84	90	39
N23	12	7	8	94	76	39
N24	13	14	10	113	125	40
N25	12	10	8	100	95	39
N26	11	7	5	86	74	39
N27	6	8	10	88	109	38
N28	12	11	10	106	112	39
N29	15	14	14	125	114	39
N30	12	9	9	100	95	39
N31	16	12	15	125	110	39
Mean	**12.10**	**10.65**	**9.19**	**103.61**	**99.16**	**38.61**
SD	**2.90**	**2.51**	**2.75**	**14.00**	**14.85**	**1.09**
Range	**3-18**	**5-15**	**4-15**	**65-125**	**74-131**	**35-40**

-1SD and <-1SD

Key:
WS=Word Series
SR= Sentence Repetition
SQ=Sentence Questions
PN=Picture Naming
NWRep=Nonword Repetition

Note: Subtest scores on the CAS relate to a mean of 10 (*SD* 3), while the CAS Quotient and PhAB PN scores relate to a mean of 100 (*SD* 15). The NWRep raw scores have a maximum of 40. The mean NWRep score of TD participants was 38.61 (*SD* 1.09).

From Table O2 it can be seen that:

TD participants also demonstrated a reduction in CAS scores as task demands increased. Only 6.45% had poor scores on the serial memory task (WS), while 16.13% and 22.58% had poor scores on the SR and SQ tasks respectively.

Only one TD participant (compared to 10 SLI participants) obtained a CAS successive processing quotient which was below average. This participant, N13 appears to have a marked memory deficit.

Only 9.67% of TD participants had low scores on the picture naming task, suggesting that the 29% of SLI participants with poor scores on this test reflect a marked deviation from the norm.

Only two TD participants (6.45%) (compared to 22 SLI participants) obtained low nonword repetition scores. Both these scores were only 1*SD* below the mean, and thus probably reflect normal variation.

Results obtained for TD participants indicate that memory difficulties are not unusual in children who are performing adequately at school. However, only three of these participants presented with low scores on more than one task, suggesting that typically developing children can compensate for weakness in one aspect of memory functioning.

Appendix P: Comparison of Deviant Speech Behaviours

Table P1: Mean occurrence, range and number of participants exhibiting deviant speech behaviours in each category.

Category	MWL		NWR		PR		SR		TT	
	SLI	TD	SLI	TD	SLI	TD	SLI	TD	SLI	TD
Word Omission	N/A	N/A	N/A	N/A	-	-	**0.26** *(0-2)* n=5	**0.1** *(0-2)* n=2	**0.39** *(0-2)* n=11	-
Semantic Word Substitution	-	-	-	-	**0.16** *(0-2)* n=4	-	**0.55** *(0-2)* n=12	**0.16** *(0-1)* n=5	**0.29** *(0-5)* n=5	**0.06** *(0-1)* n=2
Word Addition	N/A	N/A	N/A	N/A	**0.06** *(0-1)* n=2	-	-	**0.06** *(0-1)* n=2	**0.52** *(0-4)* n=8	**0.26** *(0-5)* n=4
Assimilation	**1.42** *(0-8)* n=21	**0.48** *(0-4)* n=7	**3.81** *(0-12)* n=29	**1.68** *(0-5)* n=21	**2.35** *(0-6)* n=28	**0.94** *(0-5)* n=19	**1.45** *(0-4)* n=24	**1.42** *(0-4)* n=23	**17.45** *(5-32)* n=31	**7.29** *(1-27)* n=31
Phonemic Word Substitution	-	**0.03** *(0-1)* n=1	**0.07** *(0-1)* n=2	**0.03** *(0-1)* n=1	**0.81** *(0-3)* n=16	**0.42** *(0-3)* n=9	**1.0** *(0-5)* n=12	**0.61** *(0-2)* n=12	**8.29** *(0-20)* n=28	**7.9** *(3-15)* n=31
Transposition	**0.65** *(0-3)* n=14	**0.19** *(0-3)* n=4	**1.35** *(0-5)* n=21	**0.77** *(0-4)* n=17	**0.03** *(0-1)* n=1	**0.13** *(0-1)* n=4	**0.19** *(0-1)* n=6	**0.16** *(0-1)* n=5	**0.81** *(0-4)* n=15	**0.58** *(0-2)* n=12
Substitution	**0.42** *(0-2)* n=10	**0.06** *(0-1)* n=2	**0.84** *(0-4)* n=18	**0.42** *(0-3)* n=8	**0.16** *(0-3)* n=3	**0.13** *(0-2)* n=3	**0.19** *(0-2)* n=5	**0.03** *(0-1)* n=1	**0.39** *(0-3)* n=10	**0.35** *(0-9)* n=2
Addition	**1.29** *(0-3)* n=21	**0.26** *(0-1)* n=7	**2.29** *(0-10)* n=24	**0.65** *(0-3)* n=12	**1.0** *(0-4)* n=16	**0.68** *(0-2)* n=14	**1.0** *(0-4)* n=23	**0.32** *(0-2)* n=9	**1.39** *(0-5)* n=21	**0.48** *(0-4)* n=11
Phoneme Omission	**3.19** *(0-9)* n=28	**0.9** *(0-4)* n=13	**2.39** *(0-8)* n=27	**0.55** *(0-3)* n=14	**1.1** *(0-6)* n=19	**0.23** *(0-2)* n=6	**0.65** *(0-3)* n=15	**0.35** *(0-2)* n=10	**2.13** *(0-11)* n=22	**0.94** *(0-8)* n=15
Distortion	**0.61** *(0-9)* n=5	-	**0.23** *(0-4)* n=4	-	**0.26** *(0-6)* n=3	-	**0.32** *(0-6)* n=3	-	**0.29** *(0-7)* n=2	-
Hesitation	**0.58** *(0-3)* n=14	**0.32** *(0-2)* n=8	**0.90** *(0-5)* n=13	**0.52** *(0-3)* n=11	**0.65** *(0-3)* n=11	**0.26** *(0-3)* n=5	**1.10** *(0-4)* n=21	**0.45** *(0-4)* n=9	**4.32** *(0-14)* n=30	**2.23** *(0-10)* n=24
Prolongation	**0.42** *(0-3)* n=8	**0.13** *(0-2)* n=3	**0.32** *(0-2)* n=9	**0.16** *(0-2)* n=4	**0.35** *(0-3)* n=9	**0.06** *(0-1)* n=2	**0.55** *(0-3)* n=12	**0.1** *(0-1)* n=3	**2.9** *(0-11)* n=22	**0.97** *(0-5)* n=17
Sound/Part-word Repetition	**1.42** *(0-4)* n=23	**1.19** *(0-5)* n=18	**1.39** *(0-5)* n=21	**0.84** *(0-4)* n=15	**0.81** *(0-5)* n=17	**0.29** *(0-3)* n=6	**0.61** *(0-3)* n=10	**0.26** *(0-2)* n=7	**5.35** *(0-12)* n=30	**2.94** *(0-12)* n=23
Word Repetition	**0.16** *(0-2)* n=4	-	**0.1** *(0-1)* n=3	**0.1** *(0-2)* n=2	**0.42** *(0-3)* n=9	**0.35** *(0-2)* n=9	**0.19** *(0-2)* n=5	**0.42** *(0-3)* n=10	**2.45** *(0-8)* n=5	**1.39** *(0-4)* n=22
Phrase Repetition	N/A	N/A	N/A	N/A	**0.13** *(0-1)* n=4	**0.03** *(0-1)* n=1	**0.03** *(0-1)* n=1	**0.1** *(0-1)* n=3	**0.39** *(0-2)* n=11	**0.39** *(0-4)* n=8
Revision	**1.29** *(0-7)* n=17	**0.52** *(0-4)* n=8	**1.0** *(0-5)* n=15	**0.48** *(0-4)* n=12	**2.32** *(0-11)* n=26	**1.58** *(0-4)* n=7	**1.87** *(0-6)* n=23	**1.68** *(0-7)* n=24	**14.9** *(5-29)* n=31	**8.48** *(2-15)* n=31
Interjections	-	-	**0.03** *(0-1)* n=1	-	-	**0.03** *(0-1)* n=1	-	**0.03** *(0-1)* n=1	**0.1** *(0-2)* n=2	**0.26** *(0-3)* n=4
No Response	**0.10** *(0-1)* n=3	-	**0.35** *(0-4)* n=5	**0.1** *(0-1)* n=3	**0.1** *(0-1)* n=3	-	**0.13** *(0-1)* n=4	**0.06** *(0-1)* n=2	-	-

***Key**: Mean scores are in **bold** and ranges in italics. n=number of participants presenting with this behaviour.*

Appendix Q: Description of Participants' Performance on the Oral Motor Evaluation (OME).

Note: Only items where at least one participant obtained a rating of 1 are reported below.

ITEM	SLI	TD
	STRUCTURE	
1. Lip symmetry (SLI=1)	Scar lower lip S7	
2. Relationship lips at rest (open vs closed) (SLI=2; TD=1))	Open mouth posture: S23; S30	Open mouth posture: N26
3. Lip tone (SLI=1)	Low tone: S17	
18. Symmetry mandible (SLI=1; TD=1)	Notch: S9	Notch: N18
19. Occlusion mandible (SLI=6; TD=3)	S14 Overbite: S23; S25; S29; S30 Overbite + braces: S20	Overbite: N11; N24; N26
20. Size mandible (SLI=1)	Large mandible: S12	
26. Size maxilla (SLI=1)	Small maxilla: S27	
27. Teeth: decay (SLI=5; TD=1)	S5; S6; S16; S17; S30	N15
28. Teeth: alignment (SLI=9; TD=9)	S6; S23 Braces: S10; S14; S16; S25 Lower lateral incisors behind canines: S24 Braces + plate: S26 Gap between upper medial incisors: S29	N3; N8; N10; N11; N14; N15 Plate: N20 Braces: N23; N27
29. Teeth: gaps (SLI=3; TD=4)	Widely spaced: S5; S14; S22	Gaps between upper canines and incisors: N7 Gap between medial upper incisors: N9; N15; N26
30. Teeth: missing (SLI=8)	S1: missing lateral incisors S3: upper left canine S6: chipped medial upper incisor S14 S15: missing upper canine S16: missing upper canines S26: missing upper premolars S30: missing lower left canine	
31. Teeth: occlusion (SLI=1; TD=4)	S14	N3; N9; N15; N26
33. Tongue: carriage (SLI=3; TD=3)	Notch tongue tip: S6; S19 Anterior at rest: S23	Notch tongue tip: N14; N16; N19
37. Tongue: furrowing (SLI=8; TD=6)	S3; S5; S14; S15; S20; S21; S23; S30	N2; N8; N9; N11; N18; N21
38. Tongue: size (SLI=1)	Large tongue: S22	
57. Palate: structure (SLI=1; TD=2)	High arched palate: S20	High-arched palate: N2; N14
58. Velopharynx: symmetry (SLI=5; TD=6)	Uvula deviates to left: S8; S26; S31 Uvula deviates to right: S15; S23	Uvula deviates to left: N21; N22; N23 Uvula deviates to right: N3; N9; N15
59. Uvula at rest (SLI=5; TD=2)	Long uvula: S8; S9; S10; S11; S22	Short uvula: N17 Long uvula: N26

ITEM	SLI	TD
	STRUCTURE (contd.)	
60. Tonsils (TD=1)		Enlarged tonsils: N26
61.Size of velum relative to pharyngeal cavity (SLI=3; TD=1)	Small velum: S13; S30 Large velum: S22	N20: small velum
88. Posture (SLI=7; TD=3)	Slouched: S3; S6; S9; S16; S17; S23; S30	Slouched: N6: N8; N27
90. Facial structure (SLI=1)	S12: masculine features, short broad neck; notch pinna	
	ORAL FUNCTION	
4. Lip: rounding (SLI=1)	Asymmetry: S1	
7. Lip: alternate pucker/smile (SLI=4; TD=1)	S12; S19; S22 Reduced function on right: S23	Asymmetry: N11
9. Lip seal (TD=1)		N11
22. Diagonal jaw movement (TD=1)		N3
23.Dissociation mandible/tongue (SLI=9; TD=4)	S6; S7; S8; S9; S10; S11; S26; S27; S31	N2; N12; N18; N29
40. Tongue: elevate to alveolar ridge (SLI=4; TD=3)	Asymmetry: S20 Tongue thrust: S23: S29; S30	N8 Tongue thrust: N9: N20; N26
41. Tongue: interdental (SLI=1)	S14	
42. Tongue: external elevation (SLI=9; TD=2)	S1; S4; S5; S6; S8; S9; S16; S26; S31	N3; N8
44. Tongue: external lateralization (SLI=1)	S5	
45. Tongue: slow circumoral (SLI=5; TD=1)	S4; S5; S7; S9; S10	N8
64. Respiration (SLI=3)	Clavicular breathing: S3; S6; S9	
	SPEECH FUNCTION	
15. Alternate /u/ and /i/ (SLI=2)	S15; S27	
47. Tongue: touch lateral edges to teeth /sh/ (SLI=1)	Distortion: S22	
48.Interdental /th/ (TD=1)		Difficulty sustaining: N11
52. Vowel mid (SLI=1)	Distortion: S12	
65. /pe/ repetitions (SLI=1)	S22	
66. /te/ repetitions (SLI=1)	S16	
67. /ke/ repetitions (SLI-1)	S14	
68. /peteke/ repetitions (SLI=6; TD=4)	S2; S12; S14; S15; S19; S23	N3; N4; N13; N24
71. buttercup x 4 (SLI=5; TD=2)	S7; S16; S22; S24; S30	N1; N12
72. buttercup sustained (SLI=21; TD=16)	S2; S3; S4; S5; S6; S7; S9; S13; S14; S15; S16; S19; S22; S23; S25; S26; S27; S28; S29; S30; S31	N3; N4; N5; N9; N12; N13; N17; N18; N23; N24; N25; N27; N28; N29; N30; N31
75. petticoat x 4 (SLI=2)	S16; S22	
76. petticoat sustained (SLI=17; TD=4)	S2; S3; S4; S7; S8; S9; S13; S16; S17; S18; S22; S24; S25; S27; S28; S29; S30	N4; N11; N26; N27

ITEM	SLI	TD
SPEECH FUNCTION (contd.)		
77. Prosody: rate (SLI=2; TD=2)	Slow: S6; S12	N6 Slow: N14
79. Voice: pitch (SLI=1; TD=1)	Low pitch for gender: S12:	Pitch variations: N16
80. Voice loudness (SLI=5; TD=5)	Soft: S7; S17; S18; S25; S28	Soft: N1; N6; N8; N14; N23;
81. Voice: quality (SLI=6; TD=3)	Hoarse: S7; S8; S11; S12 Breathy: S16; S27	Breathy: N7; N8 Hoarse: N20
82. Voice stoppages (SLI=2; TD=1)	S20; S27	N3
83. Nasal resonance (SLI=4; TD=3)	Nasal emission: S7; S20 Nasal snorting: S16 Hyponasal: S27:	Hyponasal: N6 (cold); N26 (tonsils) N27
84. Phonation duration /a/ (SLI=7; TD=10)	S2; S21; S26; S27; S28; S30; S31	N5; N6; N7; N10; N13; N18; N19; N22; N26; N29
85. /s/ duration (SLI=2; TD=8)	S1; S6	N8; N14; N18; N22; N25; N29; N30; N31
86. /z/ duration (SLI=3; TD=4)	S21; S26; S31	N9; N13; N21; N22
87. s:z ratio (TD=3)		N9; N18; N29
91. Intelligibility (SLI=9; TD=2)	S12: slushy and indistinct S14: braces, malocclusion S15: mumbles, omits sounds S18, S30: slushy S20: distortion of /s/ and /r/ S23: distortion of sibilants (tongue thrust) S27: slushy, braces S29: braces, distortion of /s/ because of teeth	N14: soft and indistinct obstruents N26: distorted /s/ because of tongue thrust.

Appendix R: Poor Speech Group

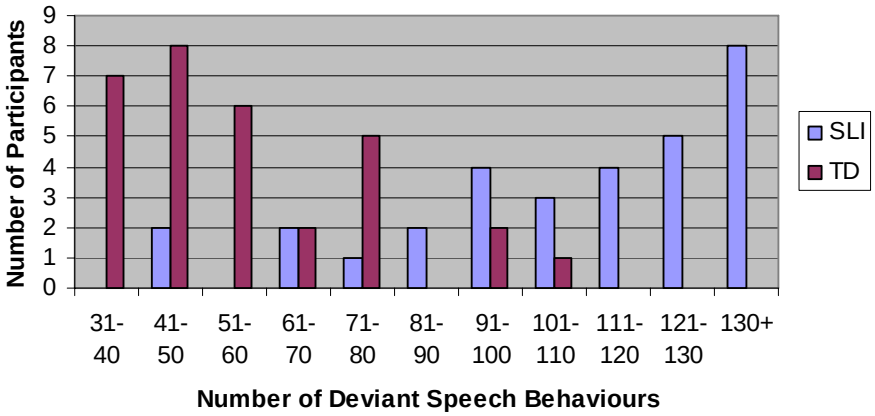


Figure R1: Comparison of Number of Deviant Speech Behaviours obtained on the Speech Assessment Battery by SLI and TD participants.

Table R1: Total Number of Deviant Speech Behaviours obtained on the Speech Assessment Battery by SLI participants.

Participant Number	MWL	NWR	PR	SR	TT	TOTAL
S1	9	7	13	9	63	**101**
S2	3	12	9	7	85	**116**
S3	25	29	19	13	83	**169**
S4	11	16	19	14	79	**139**
S5	22	18	7	8	41	**96**
S6	12	12	9	7	77	**117**
S7	2	6	9	7	68	**92**
S8	4	6	10	6	57	**83**
S9	21	13	8	7	69	**118**
S10	24	19	9	14	48	**114**
S11	3	4	5	9	44	**65**
S12	20	29	16	17	64	**146**
S13	14	23	5	6	48	**96**
S14	10	16	18	18	72	**134**
S15	10	17	7	10	57	**101**
S16	4	24	20	12	75	**135**
S17	13	13	2	9	52	**89**
S18	3	12	4	2	47	**68**
S19	13	17	13	13	73	**129**
S20	16	16	17	10	73	**132**
S21	6	6	3	4	31	**50**
S22	19	30	8	12	72	**141**
S23	15	21	10	17	59	**122**
S24	16	16	30	9	71	**142**
S25	2	16	6	6	70	**100**
S26	10	9	10	17	81	**127**
S27	13	13	9	3	70	**108**
S28	13	11	7	8	39	**78**
S29	5	13	8	3	16	**45**
S30	10	14	12	19	70	**125**
S31	10	9	10	17	81	**127**

Key:
MWL=Multisyllabic Word List
NWR=Nonsense Word Repetition
PR=Phrase Repetition
SR=Sentence Repetition
TT=Tongue Twisters

Key: Participants scoring more than 2 SD above the mean of the TD group (94 and above).

Table R2: Total Number of Deviant Behaviours obtained on the Speech Assessment Battery by TD participants.

Participant Number	MWL	NWR	PR	SR	TT	TOTAL
N1	7	4	11	5	23	**50**
N2	3	3	5	4	26	**41**
N3	7	8	12	7	67	**101**
N4	1	2	1	3	34	**41**
N5	0	0	0	7	29	**36**
N6	7	4	2	2	31	**46**
N7	0	2	3	4	35	**44**
N8	8	8	4	10	29	**59**
N9	4	8	5	12	27	**56**
N10	14	15	5	6	27	**67**
N11	8	6	7	6	48	**75**
N12	3	2	6	6	37	**54**
N13	3	9	3	5	32	**52**
N14	4	8	2	7	19	**40**
N15	0	4	9	3	21	**37**
N16	0	4	2	3	29	**38**
N17	7	11	7	4	37	**66**
N18	1	5	1	7	66	**80**
N19	1	2	6	2	28	**39**
N20	0	4	10	11	30	**55**
N21	3	10	2	3	24	**42**
N22	4	10	5	14	42	**75**
N23	13	12	8	11	49	**93**
N24	2	3	4	2	39	**50**
N25	2	1	10	17	41	**71**
N26	15	22	5	7	45	**94**
N27	2	11	7	3	31	**54**
N28	6	7	3	2	25	**43**
N29	0	4	2	3	29	**38**
N30	2	1	10	17	41	**71**
N31	0	4	2	3	29	**38**

Key:
MWL=Multisyllabic Word List
NWR=Nonsense Word Repetition
PR=Phrase Repetition
SR=Sentence Repetition
TT=Tongue Twisters

Key: Participants scoring more than 2 SD above the mean of the TD group (94 and above).