INVESTIGATION FOR SUBGROUPS IN DEVELOPMENTAL APRAXIA OF SPEECH

Thesis Submitted to the University of Mysore for the Degree of

DOCTOR OF PHILOSOPHY

IN

SPEECH AND HEARING

By

N. BANUMATHY

Guide
Prof. R. Manjula
Professor of Speech Pathology
AIISH, Mysore-570 006.

All India Institute of Speech and Hearing
Manasagangotri, Mysore - 570 006. Karnataka, India

MAY 2008

CERTIFICATE

This is to certify that the thesis entitled **"Investigation for Subgroups in Developmental Apraxia of Speech"** submitted by N. Banumathy, for the degree of Doctor of Philosophy in Speech and Hearing to the University of Mysore, was carried out at the All India Institute of Speech and Hearing, Mysore.

Date: Mysore

Place: 26-05-08

Dr. Vijayalakshmi Basavaraj
Director
All India Institute of Speech and Hearing
Mysore

CERTIFICATE

I here by certify that the thesis entitled **"Investigation for Subgroups in Developmental Apraxia of Speech"** submitted by N. Banumathy, for the degree of Doctor of Philosophy in Speech and Hearing to the University of Mysore, was carried out at the All India Institute of Speech and Hearing, Mysore, under my guidance.

Date:26-5-08

Place:Mysore

Prof. R. Manjula
Guide
Professor of Speech Pathology,
Department of Speech-Language Pathology
All India Institute of Speech and Hearing
Mysore

DECLARATION

I declare that this thesis entitled **"Investigation for Subgroups in Developmental Apraxia of Speech"** submitted herewith for the award of the degree of Doctor of Philosophy in Speech and Hearing to the University of Mysore, Mysore, is the result of work carried out by me at the All India Institute of Speech and Hearing, Mysore, under the guidance of Prof. R. Manjula, Professor of Speech Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysore. I further declare that the results of this work have not been previously submitted for any degree.

Date: 26-05-08

Place: MYSORE

N. Banumathy
Candidate
Department of Speech-Language Pathology
All India Institute of Speech and Hearing
Mysore

\

Dedicated to…

My

Parents, Sisters,

&

My Beloved Husband,

… Who have always been there for me

In each & every move of mine enabling me

Taste the essence of success!!

Acknowledgements

I express my sincere gratitude to my guide & my teacher, Prof. R. Manjula for the valuable guidance, rich corrections, and encouragement.

I extend my thanks to Dr. Vijayalakshmi Basavaraj, Director, AIISH, for her constant support, and timely advice.

I would like to express my heartfelt thanks to Dr. M. Jayaram, for his invariable support and encouragement while pursuing my doctoral program.

My wholehearted thanks to all the buddies for their extensive co-operation and patience during the longs sessions of recordings. It is you who have shaped my research so brilliantly. Thank you kiddies!!

I extend my special thanks to Shyamala ma'am for the timely help rendered in procuring the equipments and other requirements for my study.

My heartfelt thanks to Ms. Vasantha Lakshmi for clustering our thoughts put together in the statistical analysis.

I extend my respectful acknowledgements to Prof. Savithri, Dr. Venkatesan, Mr. Wilston, Dr. Rajapurohit and Vijayashree ma'am, for their valuable suggestions and input to my thesis.

I thank Shilpa and Suchitra ma'am for the untiring efforts and help rendered at various phases of my thesis.

My heartfelt thanks to Dr. Mostofsky, Dr. V, Dr. A and other experts in the field for the invaluable help in compiling the required information for my study.

Kiru, a special thanks to you...without you in my good old days, I would not have been here to pursue my doctorate in this subject. Thank you so much! I owe you a lot!!

Thanks to my dear friends, Shivu, Varghese, Anjana, JK, Shilpa, Anu, Kalai, Suma, Shankar, Mahesh, Prakash & Powlin, for the constant encouragement which helped me sustain my motivation all the way through.

"Good Life is guided by knowledge and inspired by love"

My dearest Amma, Appa, & my four adorable gems, my sisters, I owe this to you... the motivation, encouragement, moral strength that you have imparted in me and the confidence, love & faith u have in me have made me override and thrive the troubled waters to reach so far in my life. I wouldn't have been here today with out you!!

My hearty thanks to Eshumama, Murugesh anna and Pasha Sir for the constant encouragement and inspiring words at real hard times!!

My Dearest hubby, God has showered his entire blessings for all my life with a beloved gift of HIS, that is "YOU"... Thank you for always being there ***beside me*** *and guiding me in each and every move through the hurdles!! I am lost with out words to express my feelings for all that you have been doing for me!!*

Dear dad and mom (I-L), thanking you would be unappreciative for the constant moral support at crucial times, in the past two years. Still, thank you so much for offering me a helping hand at real times of need!!

Dearest Thiru and Mani akka, I am REALLY blessed to have u both in my life... It explains it all... Thanks a ton for always being there for me!!

Dear Ashwin, Sridhar, Srikant, uncle and aunty, thank you so much for your indefatigable help during various junctures towards the completion of this study. U rmore than just a friend!!

My genuine thanks to Joseph uncle for the mind-blowing discussions & invaluable suggestions, Maria and aunty for their hearty wishes and prayers, towards the completion of this thesis.

I would also like to express my gratitude to all our library staff - Lokesh Sir, Nanjunda Sir & Mahadeva Sir, for all their timely help.

Finally, I thank the Almighty for giving me the courage, will power, strength, and self confidence in each and every move of mine that helped to override the hurting barriers till today...I gave the minds to God & Hands to Work!!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

Developmental Apraxia of Speech (DAS) is a disorder seen in children with impaired ability of the speech mechanism, in the absence of obvious muscular disturbance, to execute voluntarily the expected motor gestures and programming of gestures needed for the articulation of speech (Love, 2000). DAS, referred to as Childhood apraxia of speech (CAS) by ASHA (2007) is defined as a "neurological speech sound disorder in children in whom the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g., abnormal reflexes, abnormal tone). CAS may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of known or unknown origin, or as an idiopathic neurogenic speech sound disorder. The core impairment in planning and / or programming spatiotemporal parameters of movement sequences results in errors in speech sound production and prosody".

Praxis breakdown is evident in various forms; primarily those of oral apraxia and / or verbal apraxia. As DAS is reported to often accompany oral apraxia, it is reported to affect not only speech but other aspects of oral motor co-ordination and sequencing as well. The co-occurrence of these motoric disorders with DAS has led some to suggest a purely motoric basis for this disorder (Robin, 1992). On the other hand, there is general agreement that language deficits also frequently accompany DAS. Most of the investigators however agree that the language deficits and deficits in reading / writing skills often co-occur in DAS (Dewey & Kaplan, 1992; Velleman, 2003; Gillon & Moriarty, 2007).

Generally, children with DAS exhibit congenital articulation problems, which are moderate to severe in nature and are resistant to traditional articulation and / or phonological intervention methods (Yoss & Darley 1974; Haynes, 1985; Marquardt & Sussman, 1991; Velleman & Strand, 1994; Bowen, 2006). The basic difficulty in executing and coordinating speech in children with DAS results in a high frequency of unintelligible responses (Yoss & Darley 1974; Haynes, 1985; Marquardt & Sussman, 1991; Bernthal & Bankson, 1993; Crary, 1993; Hall, Jordan & Robin, 1993; Hustad & Beukelman, 1998). The most common symptoms reported of DAS are deviant consonant and vowel productions, sequencing difficulties with phonemes and syllables, groping and trial-error behaviors, and inconsistency in articulation (Murdoch, Porter, Younger & Ozanne, 1984; Stackhouse, 1992; Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Thoonen, Maassen, Gabreels, Schreuder, & de Swart, 1997). Other neuromotor deficits such as muscular weakness and spasticity (Rosenbek and Wertz, 1972), gait abnormalities and coordination problems and reduced diadochokinetic rates (Yoss & Darley, 1974) also co-occur with DAS. The controversy however, in terms of diagnostic markers still persists, simply because the characteristics are not always unique to DAS. There are concomitant motor problems that are reported to share these dyspraxic characteristics (Deputy, 1984; Smit, 2004; Gillon & Moriarty, 2007). The communication profiles of children suspected to have DAS with a moderate inventory of speech sounds are reported to be similar to those of children with other speech-language disorders or neurobehavioral disorders (Davis, Jakielski, & Marquardt, 1998; Davis & Velleman, 2000). This raises the question of subtypes / subgroups of DAS.

Viewing the apraxias as a group of motor disorders rather than a unitary disorder, Crary (1993) hypothesized that there is possibly more than one form of DAS and that there are different types of speech / motor breakdowns depending on the component of the controlling system that is impaired. Akin to these observations, Crary (1993), felt that there was little recognition of clinical variants pertaining to oral or speech functions in children, leading to the suspicion that there could be little recognition of functional variants within the anatomical variants. In line with these views, Shriberg, Aram and Kwiatkowski (1997a) reported three types of DAS, they being: DAS as a unitary entity i.e., DAS manifesting independently, DAS existing with syndromes and DAS sub classified into subgroups. Disruption of different motor control processes is believed to create clinically different motor speech disorders in children. Thus, most of these investigators imply that the unitary term 'developmental apraxia of speech' is a misnomer. Impairment to motor control processes results in different clinical profiles, suggesting more than a single clinical variant of developmental apraxia of speech, within the realm of motor speech disorder. Hence evaluation of motor processes is said to play a major role in the clinical assessment of a child with developmental motor speech disorder. ASHA's (2007) technical report states that DAS occurs as a primary or secondary sign in children with complex neurobehavioral disorders (e.g. genetic, metabolic). Velleman (1994) describe DAS as a subgroup existing among children with moderate to severe phonological disorders, which is characterized by slow and labored speech. There are others who disagree that DAS children form a distinct etiologic subgroup (Deputy, 1984). Overall, DAS is considered as a syndrome complex. This study attempts to investigate the existence of subgroups in DAS by means of exploring the co-occurrence of DAS in children with other speech and language disorders, viz, autism (A),, phonological disorder (PD), and expressive language disorder (ELD). It is assumed that if there is co-occurrence of DAS in children with autism (A), phonological disorder (PD), and expressive language disorder (ELD), it may support the observation of ASHA (2007) that DAS occurs as a primary or secondary sign in neuro-behavioural disorders, thus strengthening the notion of existence of subgroups in DAS rather than DAS being a unitary entity.

Studies on DAS have often shown that it is difficult to define and characterize DAS since it usually accompanies other disorders. Problems that may normally co-occur with DAS are language problems, academic problems, motor skills problems, and chewing and swallowing difficulties (Hall, 2000c). Investigators have reported children with motor deficits impairing academic and language abilities (Rosenbek & Wertz, 1972; Aram & Glasson, 1979; Ekelman & Aram, 1983; Snowling & Stack house, 1983; Milloy & Summers, 1989; Dewey & Kaplan, 1992), phonological disorders (Morley, 1965; Velleman, 1994; Mc Cauley, 2007), autism (DeMyer, Hingtgen & Jackson, 1981; Jones & Prior, 1985; Ohta, 1987; Smith & Bryson, 1994; Rogers, Bennetto, McEvoy, & Pennington, 1996; Marili, Andrianopoulos, Velleman & Foreman, 2004), and stuttering (Yoss & Darley, 1974; Byrd & Cooper, 1989; Shriberg, Aram & Kwiatkowski, 1997a; McCabe, Rosenthal & McLeod, 1998; Hammer, 2002), presenting difficulty with praxis (voluntary movement) and sequencing tasks, suggesting a close relationship between praxis deficits and language-based skills.

Oral motor imitation and other motor imitation deficits are primary characteristics of developmental apraxia of speech. Page & Boucher (1998) explicitly suggested that oral and manual dyspraxia accounted for the impaired speech and signing of autistic participants. Rogers et al. (1996) reported that adolescents with high functioning autism demonstrate deficits on several oral and manual praxis tasks, and suggested that these deficits have an impact on the social and communicative functioning as well as speech. Smith and Bryson (1994) and Smith (2000) suggested that imitation difficulties of children with autism indicate atypical representational capabilities. The results of Marili et al. (2004) support a probable underlying motor-related problem consistent with apraxia of speech and / or dysarthria in a subset of individuals with Pervasive Developmental Disorder.

The consensus is that the signs and symptoms which are common in DAS are not exclusive to the disorder but may overlap with symptoms of other speech and language disorders like stuttering, autism, phonological disorder, learning disability, expressive language disorder and others. Though many studies support the notion of subgroups in DAS there is no report available which comprehensively investigates for subgroups and co-occurrence of praxis deficits in children with other developmental disabilities such as autism, phonological disorder and expressive language disorder. Methodological variations and lack of sensitive assessment procedures could be some of the factors attributing to this failure. Till date, very few attempts are made to test children with concomitant language & motor problems like ELD (Expressive Language Disorder), pervasive developmental disability (PDD), autism (A), stuttering, learning disability etc for the presence of DAS. In this study, an attempt is made to identify praxis deficits in children with concomitant speech language disorders exhibiting suspected apraxia of speech.

On the whole, the studies investigating co-occurrence of DAS in other developmental disorders are limited in number and are varied due to the underlying deficit(s) resulting in a shared set of characteristics. Some investigators propose primarily a linguistic deficit (Aram & Nation, 1982; Marquardt & Sussman, 1993; Velleman & Strand, 1994; Shriberg, Aram & Kwiatkowski, 1997 a, b, c), based on the postulation that the underlying deficit is at the level of phonological mapping, syntactical framing, or stress assignment. On the other end of the spectrum are those who feel that the deficit is at the motor programming and or planning level (Crary, 1993; Hall et al., 1993; Caruso & Strand, 1999; Square, 1999). For example, some children with DAS may have a linguistic deficit, such as poor hierarchical organization of speech sounds and syllable shapes, whereas others may have a motor sequencing deficit, or have a combination of motor and linguistic deficits.

Some studies pertaining to apraxia of speech in children have made an attempt to characterize and explain the motor and speech deficits from a functional viewpoint. Yet, there are not enough evidences to prove the functional heterogeneity in children with DAS. Many theories of apraxia suggest that there is a breakdown at different levels of control for intentional movement, probably leading to different types of apraxia, ranging from planning to executive continuum (Crary, 1993; Vander Merwe, 1997; Caruso & Strand, 1999). If this is true, clinically one can expect an overlapping symptomatology. The major issues substantiating the evidences for existence of subgroups of DAS include: a) Variability within DAS, b) DAS as a continuum disorder, c) Overlap of apraxic features or co-occurrence of DAS with other developmental speech and language disorders. This study focuses only on the third issue, that is, it attempts to explore the presence or co-occurrence of DAS in other developmental disorders such as autism, phonological disorder and expressive language disorder. In order to investigate for the co-occurrence of DAS in co-morbid disorders, there is a crucial need for a sensitive and comprehensive assessment tool.

There are no standardized measures for assessment of these children that can be used for Indian population which is multi lingual. Scales and protocols that are currently available are not standardized for Indian population and thus cannot be adapted to an Indian context. In this study attempt was made to develop an assessment tool for oral motor, oral praxis and verbal praxis skills in children with developmental apraxia of speech and children with concomitant speech and language disorders in Kannada language (a Dravidian language spoken in southern state of India, Karnataka). There is not enough evidence in the literature investigating for the presence of both oral motor and praxis deficits in children with suspected apraxia of speech. Hence this study attempts to investigate for co-occurrence of oral motor, oral praxis and verbal praxis deficits in children with concomitant speech language disorders showing suspected apraxia of speech and presenting overlapping characteristic features as seen in children with DAS.

Objectives of the study

1) To develop a protocol for the assessment of oral motor, oral praxis and verbal praxis skills in Kannada language.

2) To assess and compare the performance of two groups of subjects on oral motor, oral praxis and verbal praxis skills:

   A) Experimental Group I: Subjects with DAS without any other co-morbid language disorder.

   B) Experimental Group II: Subjects with suspected praxis deficits co-occurring with other speech language disorders:

      Group IIA - Autism

      Group IIB - Phonological Disorder(PD)

      Group II C - Expressive Language Disorder (ELD).

Subjects in Group II with suspected praxis deficits will be referred to in the study as suspected Apraxia of Speech (sAOS).

Method

Participants

Two experimental groups of participants were included in the study. All the participants were in the age range of 4 to 14 years. Lower age of four years was chosen so that the verbal corpora of children would include at least three to four words as mean length of utterance. Higher age group of 14 years was selected as speech motor maturation is reported to be complete by 12 - 14 years of age (Kent, 1976; Kent & Forner, 1980, Kent, 1997) in typically developing children.

Experimental group I included children diagnosed as presenting DAS. This group constituted 12 children (4 males and 8 females) with a mean age of 5.9 years. The performance of DAS group on the items in the protocol was compared with experimental group II (sAOS) with nineteen (19) children with co-morbid speech and language disorders, viz, autism, phonological disorder, and expressive language disorder, identified with suspected praxis deficits in the oral / verbal skills. sAOS group had seven children with Autism, six children each in ELD and PD groups. The mean age of children with Autism was 6.4 years and that of ELD and PD was 6.3 years. Diagnosis was verified by the investigator using the diagnostic characteristics suggested in DSM-IV-TR (Diagnostic and Statistical Manual for Mental Disorders) (Saddock & Saddock, 2005). The assessment was also based on clinical observations made through 10 to 15 individual interactive therapy sessions by the investigator. After confirming for the presence of typical features of DAS, the participants in group II (sAOS) were also administered a "screening checklist" (Refer Appendix I) by the investigator for further confirmation of DAS along with the detailed assessment of speech and language skills by another Speech Language Pathologist (SLP). The screening checklist included 39 items / questions, which are recognized for their sensitivity in the identification of praxis difficulties. A cut off score of 60 % was assigned to evaluate the responses on the screening checklist. Children attaining the specified cut-off criteria were identified as "at risk" for praxis errors and referred to as the 'suspected apraxic group'. The term suspected Apraxia of

Speech (sAOS) is used to refer children whose speech and prosody-voice error patterns, performance on non-speech tasks and/or case histories are consistent with developmental apraxia of speech (Shriberg, Campbell, Karlsson, Brown, McSweeny & Nadler, 2003a).

Protocol

An assessment protocol referred to as 'Assessment of oral motor, oral praxis and verbal praxis skills' was compiled and developed drawing support from various sources in the literature. The items were specifically designed to meet the needs of Kannada speaking individuals in the age range of 4 to 14 years. The verbal praxis assessment protocol was designed to assess verbal tasks in a hierarchical manner from simple to complex tasks including assessment of isolated verbal movements, sequential verbal movements, assessment of words, sentences and spontaneous speech in Kannada. The items were subjected to familiarity rating by 4-5 year old typically developing children as the lower age was 4 years for the study. A linguist was also consulted in order to determine the dialectal appropriateness of the stimuli selected. A pilot study was carried out before finalizing the protocol in order to determine the effectiveness of protocol, appropriateness of instructions, scoring and modification if any required for the tasks. The pilot study was conducted on a small number (five in each group) of subjects from the two groups (DAS and sAOS). The test protocol was also administered to ten age and gender matched typically developing children to verify the age appropriateness of tasks in the protocol.

An informed consent was obtained from parents before the actual administration of the assessment protocol. Based on the results obtained from the pilot study, appropriate modifications were incorporated in the assessment protocol. The final protocol included three sections, viz, oral motor, oral praxis and verbal praxis assessment and the protocol is presented in Appendix II.

Assessment protocol, analysis of items, and scoring

There were three major sections in the assessment protocol, which included assessment of oral motor, oral praxis and verbal praxis skills.

1. The oral motor assessment protocol incorporated two subsections: a) assessment of oral structures at rest, and b) function of oral motor structures. Three - and two-point rating scales were used to assess the items in the oral motor assessment protocol, respectively.
2. The oral praxis assessment section included assessment of isolated, and sequential oral movements. While isolated oral movements were evaluated in terms of accuracy, rate of movements and numbers of repetitions required, sequential oral movements were rated in terms of precision or accuracy of movements and sequence. The participants were instructed to imitate the movements demonstrated by the investigator. A five-point rating scale was used to assess isolated oral movements and a three-point rating scale was used to rate the motor control scores (MCS) and sequential motor scores (SMS) for the sequential oral movement tasks.

3. The verbal praxis assessment section was specifically designed to assess verbal tasks in a hierarchical manner from simple to complex tasks including isolated verbal movements, sequential verbal movements, assessment of words, sentences and spontaneous speech. Participants were instructed to imitate the verbal movements modeled by the investigator for all items except for the assessment of spontaneous speech.

    - Isolated verbal movements were rated on a four-point rating scale. The movements were scored in terms of accuracy of movements and numbers of repetitions required.
    - Sequential verbal movements were evaluated in terms of precision of movements (motor control score) and sequence (sequential motor score). These tasks were rated on two-point rating scales.
    - In word level assessment, words were analyzed for phonological processes and the processes were categorized into space, timing and whole-word errors. Word level analysis also included sequence maintenance score that was calculated per word on a three point rating scale./
    - Sentences were scored using sequence maintenance score, on a three-point rating scale. Percentages of consonants correct and vowels correct scores (PCC and PVC) were also calculated for sentence level assessment.
    - Spontaneous speech was analyzed using PCC scores, PVC scores, numbers of dysfluencies, groping, distortions and phonotactic assessment.

different investigators were involved. 30% of the data was checked for reliability measures by a second judge other than the principal investigator (judge 1). The second judge was matched in age, gender, education, and work experience with the principal investigator. The second judge was given appropriate training and/or instructions to carry out the tasks. Reliability co-efficients were established on statistical analyses along with segment to segment inter and intra-transcription reliability.

Statistical analysis

In order to compare the performance across the two experimental groups viz. participants with DAS and those with suspected apraxia of speech (sAOS), following statistical analyses were carried out for each of the three sections in the assessment protocol. They were Kruskal Wallis test, Mann Whitney U test, one-way ANOVA, Duncan's post hoc test, Friedman test, Wilcoxon signed rank test, Cluster Analysis, and uncorrelated equality of proportions.

Limitations

- The study was a preliminary attempt in terms of exploring praxis deficits in individuals with autism, Phonological Disorder (PD) and Expressive Language Disorder (ELD).
- The participants in both the groups are small since the selection of participants involved a set criterion.

- The study explored the praxis deficits employing perceptual method using a perceptual assessment tool in Kannada language, developed for this purpose. It did not incorporate objective assessment such as acoustic analysis.

Implications

The protocol developed incorporates sections for assessment of oral and verbal praxis deficits in DAS as well as sAOS, which in turn will help in differential diagnosis and setting goals for therapeutic management.

To sum up, the present study was carried out as a preliminary attempt to investigate for subgroups in DAS by means of exploring the co-occurrence of DAS in children with other developmental disorders such as autism, phonological disorder, and expressive language disorder by comparing their performance with the reference group, DAS showing typical praxis deficits. The suspected apraxia of speech groups were assessed for oral motor, oral praxis and verbal praxis skills using a perceptual assessment protocol and they were found to exhibit similar errors as the DAS group in all three domains, indicating the co-occurrence of DAS in sAOS groups.

Review of Literature

REVIEW OF LITERATURE

Speech is the product of a series of movements. The air passing through the vocal tract is constricted by the movements of various articulators and these movements result in the acoustic output of speech (Caruso & Strand, 1999). Movements that occur at the right time, range, speed, force and tension determine the acoustic output of speech. Any deviation in these parameters of movements distorts speech output and renders communication difficult. Children with "Developmental Motor Speech Disorders" exhibit deficits in speech due to disordered speech motor control (Crary, 1995). "Developmental Motor Speech Disorders" is a group of speech disorders of which Apraxia and Dysarthria are significant.

'Apraxia' refers to lack of praxis. "Praxis", as defined by Ayres (1985), is "that neurological process by which cognition directs motor action, the ability to plan or formulate different actions that allow the individual to affect the relationship between self and the environment (which)...occurs before actual motor execution". According to this definition, movement pattern is not only a series of postures, but includes a motor plan about the sequencing of these postures, which does not simply consist of the order of occurrence. In other words, praxis is the generation of volitional movement patterns, including the selection, planning, organization and initiation of movements. Velleman and Strand (1994) define *praxis* as the ability to select, plan, organize and initiate the motor pattern (for a particular action). Velleman (2003) suggests that execution of motor movements is merely the result of praxis, i.e., the overt manifestation of an invisible process called motor planning which determines how the articulators (or other body parts) transit from one posture to the next. The transition involves a fine tuned awareness and plan for smooth transition from the current to the desired future state of articulators at any given moment. Lack of praxis or apraxia is seen in various forms such as oral and verbal apraxia and others. *Oral apraxia* refers to difficulty with volitional control of nonspeech movement. *Verbal apraxia* refers to difficulty with volitional control of speech movements. Oral apraxia without verbal apraxia is reported to be very uncommon (Velleman, 2003).

The disorder of 'Developmental Apraxia of Speech' (DAS) is surrounded by confusion and controversy (Bernthal & Bankson, 1993). There is little agreement among experts regarding a descriptive label, definition, salient characteristics, assessment procedures and intervention approaches for children with DAS (Guyette & Diedrich, 1981; Marquardt & Sussman, 1991; Hall, Jordan & Robin, 1993). Various terms or labels are used to describe the disorder of DAS and these include, developmental apraxia of speech (Rosenbek & Wertz, 1972; Strand & McCauley, 2000), developmental verbal apraxia (Edwards, 1973), acquired articulatory apraxia (Morley, 1965), verbal dyspraxia (Velleman & Strand, 1994), developmental verbal dyspraxia (Davis, Strand, & Velleman, 1998), and congenital articulatory apraxia (Eisenson, 1972). The terms reflect different views about the cause of the disorder, and not differences in the defining characteristics of the disorder. *Childhood Apraxia of Speech* is the most recent and recommended term for describing apraxia of speech in children (ASHA, Ad Hoc Committee technical report, 2007). In this study however, the term Developmental Apraxia of Speech (DAS) is used.

Review of literature in further sections highlights various issues in DAS from neurological, neuro-behavioural, and linguistic perspectives.

1.0 Definition of DAS

The controversy begins from the fundamental issue of what to call the disorder (Morley, 1965; Rosenbek & Wertz, 1972; Yoss & Darley, 1974; Martin, 1974; Aram & Glasson, 1979; Williams, Ingham & Rosenthal, 1981; Shriberg & Kwiatkowski, 1982; Crary, 1982, 1984; Stark, 1985). The definition proposed by various investigators for DAS vary from one another. Some describe DAS as an independent entity from severe phonological disorder, and others address the salient diagnostic markers of DAS. Table 1 shows the summary of few definitions proposed for DAS.

Table 1: Definitions of DAS as proposed by various investigators

Investigator (s)	*Definition*
Williams (1988)	Apraxia is the difficulty experienced in forming sounds into words. The term developmental apraxia is used when children have this problem.
Hall, Jordan & Robin (1993)	DAS is a diagnosis based on speech characteristics that are seldom uniquely descriptive of the disorder.
Crary (1993)	DAS is a continuum that spans from oral motor processing difficulties to language processing difficulties with all parts of the continuum containing a motor planning component.
Hayden (1994)	DAS, in its purest form, is a disorder of the ability to translate phonemic and linguistic codes to differing planes of movement over time.

Velleman(1994)	DAS is a disorder of uncertain etiology and a complex of symptoms, including an oral-motor planning deficit for speech.
Thoonen, Maassen, Gabreels, Schreuder &de Swart (1997)	DAS is a disorder of sensory integration that interferes with the ability to plan and execute speech motor tasks.
Davis, Jakielski & Marquardt(1998)	DAS is a neurological disorder that affects the planning and production of speech.
Whitebread, Dvorak, & Jakielski (1999)	DAS is a disorder in children, which is exhibited as speech deficits in the absence of paralysis or weak musculature. DAS is a loss in the ability to voluntarily position the articulators (e.g., lips, jaw, and tongue) on a consistent basis when speaking. This disorder interferes with the child's ability to sequence sounds into words.
Love (2000)	DAS is a disorder seen in children with impaired ability of speech mechanism, in the absence of obvious muscular disturbance, to execute voluntarily the expected motor gestures and programming of gestures needed for the articulation of speech.
American Speech Language and Hearing Association (ASHA, 2002)	DAS is a disorder of the nervous system that affects the ability to sequence and say sounds, syllables, and words. It is not due to muscular weakness or paralysis. The problem is related to the brain's ability to plan and move the body parts needed for speech.
Marquardt, Sussman, Snow & Jacks (2002)	DAS is a neurologically based disorder affecting the programming of articulatory movements. The speech motor problems exhibited in DAS might be due to lack of phonological framework in a child's language system.
Smit (2004)	Developmental verbal dyspraxia is used to designate children with a relatively severe impairment of speech sound production (including prosody) with difficulty in planning and sequencing of speech sounds.

The definitions proposed up to the year 2004, generally point to a range of issues addressing the underlying deficit in the overt speech to a concealed deficit at a higher level of planning and programming movement patterns for speech. Most of the definitions however, agree that there is deficiency in planning or programming speech gestures. Considering the significance of the definition of DAS for children, caregivers, clinicians and researchers and also the need for revision based on emerging research findings, the technical report by American Speech - Language - Hearing Association (ASHA) Ad Hoc Committee (2007) proposed a working definition of DAS *(Childhood Apraxia of Speech - CAS* is the recommended term for use by ASHA Ad Hoc Committee, 2007) as follows:

"Childhood apraxia of speech (CAS) is a neurological childhood (paediatric) speech sound disorder in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g., abnormal reflexes, abnormal tone). CAS may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of known or unknown origin, or as an idiopathic neurogenic speech sound disorder. The core impairment in planning and/or programming spatiotemporal parameters of movement sequences result in errors in speech sound production and prosody".

According to ASHA Ad Hoc Committee (2007), a definition of DAS should ideally comprise three elements: description of the *core problem,* attribution of its *cause or etiology,* and listing of one or more *diagnostic signs or markers.* The definition proposed by ASHA Ad Hoc Committee (2007), invariably include the proposed core problem, it may or may not address the other two elements. One of the major differences in the alternative definitions of DAS is whether the proposed core problem includes input processing as well as production. While some of the definitions of DAS reviewed by the Committee view the core problem as one of planning and programming the spatiotemporal properties of movement sequences underlying speech sound production, others propose that the deficit extends to the representational-level, segmental and / or suprasegmental units in both input processing and production (ASHA Ad Hoc Committee, 2007).

2.0 Characteristics of Developmental Apraxia of Speech

The controversy that manifests itself in the definition of the disorder also extends to what characterizes the disorder. Despite the controversy, some characteristics are generally agreed upon as being commonly manifested in children with DAS. Hall (2000a) summarized these characteristics as follows:

- Children with DAS generally are quiet babies who do not babble / coo like their typically developing peers (Hall, 2000a; ASHA, 2002).
- They have slow / late development of speech skills (Hall, 2000a; ASHA, 2002; Marquardt, Sussman, Snow & Jacks, 2002).
- They have problems sequencing vowels and syllables correctly (Forrest, & Morrisette, 1999; Hall, 2000a; ASHA, 2002; Marquardt, Sussman, Snow & Jacks, 2002).

- Their performance on speech tasks is inconsistent (Davis, Jakielski and Marquardt, 1998; Forrest, & Morrisette, 1999; Hall, 2000a; Marquardt, Sussman, Snow & Jacks, 2002).
- They may have "groping" or "silent posturing" of tongue, lips or jaw (Forrest, & Morrisette, 1999; Hall, 2000a; ASHA, 2002).
- They have problems in uttering the correct vowel in the word (Davis, Jakielski and Marquardt, 1998; Forrest, & Morrisette, 1999; Hall, 2000a).
- They produce distorted or incorrect prosody (Davis, Jakielski and Marquardt, 1998; Hall, 2000a; Marquardt, Sussman, Snow & Jacks, 2002).
- Their speech may sound hypernasal (Hall, 2000a).
- They generally do not have problems with receptive language, cognitive deficits, and muscle weakness (Dewey, 1995; Hall, 2000a; ASHA, 2002).

Further, Strand and McCauley (2000) listed some of the characteristics of DAS as follows:

- Receptive language is superior to expressive language skills.
- Oral apraxia may or may not exist with DAS (Walton, Ellis, & Court, 1962; Rosenbek & Wertz, 1972; Yoss & Darley, 1974; Ferry, Hall, & Hicks, 1975; Horwitz, 1984; Marquardt, Dunn, & Davis, 1985; Hall, Hardy, & LaVelle, 1990; Love, 1992; Pollock, & Hall, 1991; Velleman & Strand, 1994).
- Phonemic errors are often seen in the form of sound omissions.
- They experience difficulty in achieving the initial articulatory configuration.

- There is increase in errors with increase in word length and phonetic complexity.
- Connected speech is poorer than word production.
- Errors occur more frequently on the complex sounds, for example fricatives (i.e., /s/, /z/, /ʃ/, etc.), affricates (i.e., ,/tʃ/, /j/), and consonant clusters, (i.e., /st/, /sp/, /sl/, etc).

Davis and Velleman (2000) list the following characteristics as most descriptive of DAS in very young children:

- Restrictions and gaps in sound repertoire (both consonant and vowel), including the possibility that the child may have acquired some later developing sounds while missing earlier developing sounds.
- These children may demonstrate very limited use of syllables, possible use of an extended single sound or few vocalizations at all. The children may have difficulty combining the sounds that they have.
- Limited variation of vowels and the use of a centralized vowel for multiple purposes.
- Vocalizations may have speech-like melody but syllables or discernable words may not be present.
- Words may seem to disappear from use more than would be expected in a typically developing child of the same age.
- Predictable utterances may be easier than novel utterances

Additional nonspeech characteristics identified by Davis and Velleman (2000) that may be suggestive of apraxia of speech in young children include: use of homemade gestures or signs, some feeding difficulties such as eating mixed textures, drooling, overall late development of motor skills, and oral motor in coordination.

Velleman (ASHA, 2007) thus summarized apraxia or dyspraxia as a disorder of:

- Volitional movement (Dewey, Roy, Square-Storer, & Hayden, 1988 ; Nelson, 1995; Maassen, Groenen, & Crul, 2003).
- Spatial-temporal coordination (Sussman, Marquardt, & Doyle, 2000 ; Nijland, Maassen & Van der Meulan, 2003).
- Motor sequencing (Crary & Anderson, 1991).
- Carrying out or learning complex movements (Crary & Anderson, 1991).
- Central sensorimotor processes (Crary 1984).
- Accommodation to context (coarticulation) (Maassen, Nijland & Van der Meulan, 2001; Nijland, Maassen, Van der Meulan, Gabreels, Kraaimaat, & Schreuder, 2002, 2003).

The characteristics listed above are not always unique to DAS. There are concomitant motor problems which share these dyspraxic characteristics (Deputy, 1984; Smit, 2004). Even though various investigators agree upon the aforementioned characteristics, controversy in terms of the diagnostic markers persist (Deputy, 1984; Marquardt & Sussman, 1991; Thoonen, Maassen, Gabreels, & Schreuder, 1994; Forrest &Morrisette, 1999).

2.1 Diagnostic considerations in DAS based on the characteristics

The disagreements over the definition of DAS continue to the description of its characteristics. Based on review of literature, Thoonen et al. (1997), summarizes the symptoms indicative of DAS as including *deviant consonant and vowel productions, sequencing difficulties with phonemes and syllables, groping and trial-error behaviors, and inconsistency in articulation.*

Although several types of phonological errors mark DAS (Rosenbek & Wertz, 1972; Aram & Glasson, 1979; Crary, Landess & Towne, 1984; Jackson & Hall, 1987; Pollock & Hall, 1991), the relative frequency of various types of errors is still not understood (Thoonen et al., 1997). A comprehensive assessment of all possible error types with in a study and differentiation of consonant patterns was suggested by Thoonen et al. (1997). Thoonen et al. (1997) found consonant substitutions as the most frequent error type followed by distortions and omissions. A developmental pattern was observed with omissions as common errors in younger children and substitutions in older children. These findings corroborate well with the high substitution rates than omission rates in children with DAS reported in previous studies (Aram & Glasson, 1979; Crary, Landess & Towne, 1984; Jackson & Hall, 1987).

Although a high rate of cluster reduction was reported as a diagnostic sign of DAS (Crary, 1984; Crary, Landess & Towne, 1984; Pollock & Hall, 1991), it is not an exclusive sign of DAS as they are also reported in non-apraxic phonologically disordered children (Parsons, 1984), unintelligible children (Hodson & Paden, 1981) and children with language delay (Dunn & Davis, 1983; Morrison & Shriberg, 1992).

Shriberg, Aram and Kwiatkowski (1997a; 1997b) reported that disorders of prosody characterized only a subgroup, but not all children with DAS. David, Jakielski and Marquardt (1998) consider increased variability as major characteristic of significance for differential diagnosis of DAS. The other speech characteristics included, a) prosodic abnormalities, b) vowel errors, and c) error variability. They also reported that although none of the characteristics appears to be unique to DAS alone, both speech and nonspeech characteristics are present in the syndrome of DAS.

Strand (2003) identified five diagnostic characteristics of apraxia in children and they include:

- Difficulty in achieving and maintaining articulatory configurations.
- Presence of vowel distortions.
- Limited consonant and vowel repertoire.
- Use of simple syllable shapes.
- Difficulty completing a movement gesture for a phoneme easily produced in a small but not in a longer linguistic unit.

DAS being a highly variable disorder amongst children, it is seen that characteristic cluster of symptoms also vary in this group. However, some characteristics are reported to be more consistent in DAS and these are elaborated in the following sections.

-f—*•

2.1.1 Inconsistency and Variability of speech in DAS

Consistency of production, or lack of consistency, has received considerable attention in investigations of children with speech disorders. Inconsistency (often referred to as variability) is one of the key diagnostic markers of developmental apraxia of speech (Dodd and McCormack, 1995; Davis, Jakielski and Marquardt, 1998, 2004; Forrest, 2003). Measures of variability and inconsistency reported in studies vary due to methodological considerations [Schumacher, McNeil, Vetter & Yoder, 1986 (as cited in Hall, Jordan and Robin, 1993); Smith, Marquardt, Cannito & Davis, 1994; Dodd, 1995; Shriberg, Aram & Kwiatkowski, 1997; Ingram, 2002; Tyler, Lewis & Welch, 2003].

Variability refers to the tendency to make different errors during multiple productions of a given sound in the same context (same word or phrase, same position in the word). For example, for repeating the word "pen" multiple times on three consecutive trails, a DAS child may produce words such as "fen", "Sen", "kren". Since the error on the initial "p" sound varies from time to time in the same place in the word and in the same context, it is identified as a variable production. *Consistency* refers to the tendency to produce errors in the same place on repeated trials in the same context. For example, if the target word is "pen" and the child produces words such as "fen," "pef," and then "pof', these productions are considered inconsistent since the errors change in positions on repeated trials. A critical issue in describing the characteristics of DAS is to observe whether the productions are variable and / or inconsistent.

Dodd (1995) suggested that extensive variability may be viewed as an inconsistent phonological disorder, reflecting an underlying 'phonological planning' deficit (i.e. an incomplete or degraded phonological plan). Bradford and Dodd (1996) reasoned that inconsistent speech output could be due to creation of new plans each time they produce a particular word. Robin (2003) believes that children with DAS are consistent in that they tend to produce errors in the same place on repeated trials, but the errors are variable. That is, children with apraxia mostly produce error types of distortions or substitutions, which are relatively consistent but vary from trial to trial. Robin (2003) also observed that distortions were more consistent error types. Investigators suggest that children with variable substitution patterns represent a unique group that may benefit from a specific type of intervention (Dodd, 1995; Dodd & Bradford, 2000; Forrest & Elbert, 2001). Analysis of variable and consistent error types has important implications in the identification of subgroups of children with phonological disorders.

2.1.2 Vowel errors in DAS

Children with Developmental Apraxia of Speech (DAS) are highly likely to experience difficulties in the production of vowels. Vowel errors are often considered as potential diagnostic marker (Ball & Gibbon, 2002), characteristic feature (Morley, 1959; Rosenbek & Wertz, 1972; Davis, Jacks, & Marquardt, 2005), persisting and a differentiating feature of DAS (McCabe et al., 1998).

Variability in vowel errors is reported by few investigators (Smith, Marquardt, Cannito & Davis, 1994). In adult apraxic subjects, the variability was attributed to difference in the length of linguistic units in which vowels are embedded (Yoss & Darley 1974). Banumathy and Manjula (2007), reported variability in vowel duration with increase in length of linguistic units in children with DAS. Nijland et al. (2002) reported poor differentiation of vowels in children with DAS. In a comparative study, Nijland, Maassen and Van der Meulan (2003) observed variability or change in co-articulation patterns when a bite block was placed between the teeth of typically developing children in the ages 5 and 6 years, and children with DAS. In typically developing children, decreased accuracy of vowel production and increased segment durations were attributed to limited changes in variability and co-articulatory patterns. On the other hand, in children with DAS, the vowel accuracy and coarticulation improved in the bite block condition, which in turn suggested motor programming deficits in children with DAS.

Vowel errors are most often studied using auditory-perceptual evaluation procedures by various investigators (Pollock & Hall, 1991). Lewis, Freebaira, Hansen, Iyengar, and Taylor (2004) compared three groups of children (DAS, non-DAS speech sound disorders and speech and language disorders) at school age and reported that vowel errors were characteristic in DAS group compared to other groups. Davis et al. (1998) considered limited consonant and vowel repertoire and high proportion of vowel errors as diagnostic characteristics of DAS along with six other features. ASHA technical report (2007), states that inconsistent vowel errors in repeated productions of syllables or words reflect a deficit in planning and programming of movements for speech in children with

DAS. They also state that phonetic distinctiveness of vowel is reduced in the speech of children suspected to have DAS (Nijland et al., 2002). Vowel errors are significant because they have a direct impact on intelligibility and can have serious consequences on consonant production. Assessment of vowel errors in children with DAS is however particularly challenging.

2.1.3 Lexical stress ratio and Co-efficient of variation ratio

Apart from the segmental errors reported in the speech of DAS, inappropriate stress patterns as a prominent prosodic error are also well documented in the speech of children with DAS (Shriberg, Aram and Kwiatkowski, 1997c). Reduced distinctions between stressed and unstressed segments are often reported in these children when compared to typically developing children. Odell and Shriberg (2001) attributed inappropriate stress in the speech of some children with suspected DAS to both representational and speech motor control processing. Shriberg, Paul, McSweeny, Klin, Volkmar, and Cohen (2001) observed destressing of stressed syllables and over stressing of stressed syllables in children with DAS. They further observed that destressing could be consistent with a representational deficit, and overstressing with a speech motor processing deficit.

Shriberg et al. (2003 a, 2003b) proposed Lexical Stress Ratio (LSR) and the Coefficient of Variation Ratio (CVR) as two sensitive measures aiding the diagnosis of individuals with suspected Apraxia of Speech (sAOS). The LSR is a weighted composite score (duration, amplitude and frequency area) of the stressed and unstressed vowels produced in eight trochaic word forms. The composite lexical stress ratio quantifies the acoustic correlates of "inappropriate lexical stress" in bysillabic forms, which is reportedly prevalent in children with suspected SD-AOS (Speech Delay - AOS). Inappropriate lexical stress is explained as excessive stress or lack of stress on a syllable that is normally stressed. Three acoustic features are used to measure lexical stress included frequency area, amplitude area, and duration of the first and second vowels in trochaic words. Both high and low LSR values are said to be associated with sAOS.

Shriberg and Mc Sweeny (2002) viewed high stress ratios (excessive stress on the stressed syllable) as supportive of possible deficits in speech motor control processes. Low stress ratios were reported to indicate relatively greater stress on the unstressed syllable, reflecting possible deficits in linguistic representational processes or speech motor processes (inappropriate representation of stress and/or inappropriate speech motor realization of the unstressed syllable). Akin to these conclusions from indirect evidences, Shriberg et al. (2003a) addressed the possible psycholinguistic locus of a stress deficit as a prominent feature in most of the children with sAOS. This was based on the relatively continuous scores of sAOS participants varying from stressed - to - unstressed syllable ratios (i.e., an excessive stress on the stressed syllable) that seemed to be more consistent with the concept of a praxis deficit in speech motor control. However, Shriberg et al. (2003a) also pointed that not all children with sAOS showed a prosodic deficit. This finding was more supportive of DAS as a unitary disorder of speech praxis with variable expression of severity and error topology. Thus, they proposed that an increase in LSR scores implicates a praxis deficit in pre-speech planning or programming stages (Odell &

Shriberg, 2001) rather than a linguistic representational deficit (i.e., deficit in underlying phonological representation of lexical stress).

The term Co-efficient of Variation Ratio (CVR) refers to the normalized variability in the durations of speech and pause events of each utterance of a subject. In other words, CVR is a measure of temporal variability in the speech of children with sAOS. The metric CVR is derived by dividing the co-efficient of variation for pause events by the co-efficient of variation for speech events, which expresses the speaker's relative temporal variation in two domains. A higher coefficient of variation ratio and proportionally more variation in the duration of pause events were reported in children with sAOS than in those groups with speech delay and normal speech (Shriberg, Hosom, & Green, 2004). In other words, there were less variations in the duration of speech events, thus leading to the interpretation that there is a *constraint in speech timing* and this could therefore be a core feature of the praxis disorder that defines a developmental form of apraxia of speech.

Thus, a few characteristics such as vowel errors, inconsistent and inappropriate stress are considered as distinct diagnostic signs of Developmental Apraxia of Speech. It is always a challenge to diagnose DAS due to overlapping symptoms and co-occurring disorders. This in itself gives rise to questions on possible existence of subgroups in DAS. The studies, which address the issue of subgroups in DAS either directly or indirectly is presented in the next few sections.

3.0 Notion of Subgroups in Developmental Apraxia of Speech

The diagnosis of DAS in young children lacks a "gold standard". Gold standard refers to a diagnostic characteristic that, when present, must lead to a definite diagnosis of DAS. The diagnostic criteria used in research often vary from study to study as researchers strive hard to find a feature or set of features that could be considered as the gold standard (Davis, Jakielski, & Marquardt, 1998; Strand, 2002). Differential diagnosis is facilitated only with the availability of one or more validated diagnostic markers for a disorder or disorder subtype (Shriberg, Aram, & Kwiatkowski, 1997a).

Given the extensive behavioral characteristics that mark the disorder of DAS, there are opinions suggesting the possible existence of subgroups in DAS, reflecting differential involvement of speech-motor and cognitive-linguistic functions (Yoss & Darley, 1974; Williams, Ingham & Rosenthal, 1981; Hayden & Square, 1993; Hayden, 1994). Few investigators have attempted to identify the characteristics of subtypes of DAS. Substantial evidences for the existence of subgroups have been drawn from the neurological, neuro-behavioural, and linguistic substrates.

3.1 Developmental Apraxia of Speech (DAS): Neurogenic base

Neurodevelopmental substrates of speech-sound disorders are well supported in the literature. For example, speech therapy for clients with motor speech disorders is based on the hypothesis that some children have significant deficits in 'oral sensation', 'oral-motor development', 'sensory-motor integration' and other currently unsupported explanatory constructs (Horwitz, 1984; Moore & Ruark, 1996; Weismer, 1997; Forrest, 2002). Marion, Sussman & Marquardt (1993) observed that some form of brain dysfunction is implicitly assumed in DAS despite a lack of documented neurological deficits in majority of children diagnosed as having DAS. In order to understand the underlying deficit, clear knowledge about the neural basis for normal speech production and the underlying neural substrates for disordered speech is necessary. Motor speech disorders vary widely in type or quality, which relates to the location and extent of the nervous system damage. Children with motor speech disorders may have problems with the production of specific sounds, sound sequences, and at a higher level, simple sentences.

In DAS, voluntary speech production is affected. Consequently, the planning, coordination and timed execution of the movement patterns of speech are impaired (Hayden, 2002). In order to produce normal speech, control at various levels of the motor system is necessary. Nerve impulses coming from the brain transmit along the neural pathways to the muscles and structures of the speech system. The muscles of the lungs, vocal folds, velum, tongue, lip, and jaw create flows and air pressure that is perceived as speech. Neurogenic insult can affect muscle strength, muscle tone, and timing of these structures.

Based on theoretical distinctions, classical neurology places verbal and oral dyspraxic disturbance in the category of 'higher cerebral functions, suggesting that lesions are at the highest level of motor integration in the nervous system'. Motor disintegration of the neural network is implicated at three higher levels of speech production, viz, planning, programming and execution. However, neurological evidences supporting this view is limited and controversial (Horwitz, 1984).

Motor systems are described as interactive and hierarchical, comprising different levels of control and interactions between the levels. The final output is a coordinated movement, which could be of three types: reflex, automatic and skilled actions. Since speech is a skilled action, the cortex generates the command signals that drive the motor neuron pools to produce smooth, sequential, and coordinated movements necessary for speech. Motor templates for the speech act (referred to as motor programs or central patterns) are refined and stored for activation through learning. Furthermore, overlapping representations of oral structures are well designed for generating control signals for speech involving movements of many oral structures which require precise coordination (Smith, Goffman & Stark, 1995). Impairment of motor abilities is thus considered the underlying core for the speech disturbances seen in Developmental Apraxia of Speech (Hayden, 2002). Deputy (1984) also reported that dyspraxic children experience a degree of general motor in-coordination. Rosenbek and Wertz (1972) found that in their study, 26 % of children with DAS had a combination of apraxia and dysarthria, while 16% had a combination of apraxia, aphasia and dysarthria. Varying neuromotor deficits such as muscular weakness and spasticity (Rosenbek and Wertz, 1972), gait abnormalities, coordination problems and reduced diadochokinetic rates (Yoss & Darley, 1974) are reported to co-occur with DAS. Any motor activity, whether it is twirling / speaking / chewing, depends on proper timing and amplitude of muscular movements.

Van der Merwe (1997) proposed that when a person decides to communicate verbally, the message transforms from an abstract idea to meaningful linguistic (language) symbols, during which syntactic, morphological, and phonological planning occurs. This linguistic-symbolic planning is presumed to take place at the pre-motoric (non-motor) phase. The language message is then transformed into a code that can be handled by a motor (movement) system, such as the speech system. This transformation of the code occurs in three different phases or hierarchical levels of organization (Jacobson & Goodale, 1991). Speech motor planning, motor programming and execution are the three different phases in the preparation and actual production of speech movements (Marsden, 1984; Brooks, 1986; Gracco & Abbs, 1987). *Speech motor planning* entails the formulation of the strategy / plan of action by defining motor goals. This is the highest level which is mediated by the association cortex (e.g., prefrontal, parietal, and temporal lobes), which generates overall invariant motor plans. Each speech sound has a core motor plan that contains a number of motor goals. Motor goals for speech production is found in the spatial (place and manner of articulation) and temporal (timing) specifications of movements for speech sound production. During speech motor planning, the different motor goals for each speech sound are identified and arranged to occur concurrently and sequentially. Darley, Aronson & Brown (1975) suggest that the phase of spatial temporal planning of movement corresponds to syntactic planning during speech production. More often, the motor planning stage is equated to phonological planning (Gracco & Abbs, 1987). Subsequently, the strategy (motor plans) must be converted into motor programs (tactics) at the middle level, which consists of the sensori motor cortex, cerebellum and putamen loop of the basal ganglia. Motor plans are structure-specific, while programs are muscle-specific. At this stage, the specific parameters of movement such as amplitude and speed are defined. During *motor programming,* muscle tone, movement velocity, force and range as well as mechanical stiffness of the joints are specified. The repeated initiation of muscle-specific programs is also controlled during programming. An analogy of the plan-program relationship is found in other movements of the body. Planning and programming of movement occur prior to the execution of movement. The plans and programs are transformed into actual movements during the *execution* phase. At this lowest level of execution, programs are translated into muscular activity and motor acts are performed (Marsden, 1984; Brooks, 1986).

The different phases of motor planning, motor programming and execution are controlled by the coaction of various areas in the brain. A disorder in each of these phases may lead to different communication problems. The linguistic-symbolic planning phase is controlled by the temporal-parietal areas and Broca's area. A disorder at this level probably may lead to aphasia. Broca's area, the supplementary motor area (SMA) and areas 5 and 7 in the parietal lobes are presumed to control motor planning. A disorder at this level may lead to apraxia of speech in both its developmental and acquired form. Motor programming is controlled by the basal ganglia, lateral cerebellum, SMA and fronto-limbic system. A disorder at this level may lead to dysarthria and possibly stuttering. Motor execution is controlled by the cerebellum, basal ganglia, motor cortex and motor units in the muscles. A disorder at this level can lead to dysarthria.

Developmental apraxia of speech (DAS), according to Van der Merwe (1997) is the result of an inability to learn and control motor planning of speech. The underlying problems result in inability to produce speech sounds, string of sounds, combination of sounds and sounds in long or unfamiliar utterances. The child may also exhibit struggle behavior during speech production. Within the context of this theoretical framework, Van der Merwe (1997) recommends that the treatment for DAS should address the underlying substrates involved in speech motor planning.

Caruso and Strand (1999) proposed a model by adapting from Kent, Adams and Turner (1996), Gracco (1987, 1991), Levelt (1989) and Vander Merwe (1997), to describe motor speech disorders in children. The model describes various levels of neural processing that relate to the formulation of speech, and motor speech disorders that may result from deficits in these processes. It emphasizes on sensorimotor control processes underlying normal and pathologic speech output and other interactive language formulation processes of phonology, morphology and syntax. It shows that language and motor processes interact and are so inextricably linked that they cannot be separated. In the model, impairment at different levels of speech processing and its causal relationship with different types of motor speech disorders is highlighted.

In summary, although DAS is referred to as a neurogenic speech disorder, empirical evidence for neurological insult is lacking in most cases (Aram & Glasson, 1979; Gubbay, 1978; Horwitz, 1984; Thoonen et al, 1997). Further, specific sites / loci of neurogenic insult are not often reported in DAS. The neurogenic insult is reported to be scattered, not confined to single site and multiple in nature. This has given rise to the observation that DAS is not a single disorder but a syndrome complex with different cluster of characteristics. It is also suggested that there is a continuum in these characteristics and is directly proportionate to the extent of neural involvement. In other words, the behavioural correlate of neural insult is varied in this disorder.

3.2 Neuro - Behavioural Correlates of DAS

There are at least two views proposed with reference to DAS by David, Jakielski and Marquardt (1998):

1) that it is purely a motor speech disorder with difficulty in planning, initiating and carrying out motor sequences (Robin, 1992; Hall, Jordan & Robin, 1993) with some accompanying linguistic deficits, or

2) that it is a linguistic disorder with articulatory consequences.

As DAS is often accompanied by oral apraxia, it is reported to affect not only speech but other aspects of oral motor co-ordination and sequencing as well. The co-occurrence of other motoric disorders with DAS has led some to suggest a purely motoric basis for this disorder (Robin, 1992), thus supporting the first view that it is a pure motor speech disorder.

The second view postulates that the underlying deficit is an inadequacy in the underlying representations of speech segments and suprasegmentals, leading to cognitive and linguistic difficulties as well as motor sequencing difficulties (Velleman & Strand, 1994). This view presumes that children with DAS have difficulties with auditory perception of speech (Bridgeman & Snowling, 1988) and that these children have deficits in vocabulary (Velleman & Strand, 1994).

Crary (1993) proposed a third view: that DAS is a motor-linguistic deficit that includes deficits in the translation of idea (meaning) to planning and executing the required motor movements.

Smit (2004) proposed DAS as a hybrid of all the above three views. Smit (2004) considers DAS to be primarily a disorder of planning and execution of sequences of movements. These views support the notion that there is an overlap in the symptoms seen in DAS. The potential role of a motor component is often discussed in most of the developmental speech and language disorders like in DAS. The overlap of symptoms are not exclusive to DAS, but may occur with other developmental speech and language disorders. For example, phonological processes such as metathesis, initial consonant deletion, reduplication, which are characteristic of DAS are also well reported in children with phonological disorder and stuttering. A subtle motor deficit is also reported in the disorder of Specific Language Impairment, in which expressive speech and language skills are implicated. Motor issues of unspecified nature are cited as one of the factors in phonological disorders and speech motor skills are implicated in stuttering (Smith, Goffman & Stark, 1995). The unspecified nature of motor deficit associated with phonological disorders or stuttering in children poses difficulty in differentiating a confirmed case of DAS from other developmental disorders. In other words, since DAS is a syndrome with characteristics overlapping with that of other developmental disorders, the implications are multifold with respect to differential diagnosis and therapeutic requirement.

3.2.1. Developmental Apraxia of Speech - Syndrome Complex

Aram (1984) referred to DAS as a syndrome complex. The term syndrome complex is used when "a disorder presents not only distinguishing characteristics of the disorder, but characteristics that could overlap with other developmental speech and language disorders" (Aram, 1984). Velleman (1994) describes DAS as a subgroup existing among children with moderate to severe phonological disorders, which is characterized by slow and labored speech. There are others who disagree that DAS children form a distinct etiologic subgroup (Deputy, 1984). Most of the investigators however agree that the language deficits and deficits in reading / writing skills often co-occur in DAS (Dewey & Kaplan, 1992; Velleman, 2003; Gillon & Moriarty, 2007).

Although the characteristic features of DAS are well documented in literature, the motoric, linguistic and motor-linguistic issues remain debated. Several theories were developed in an attempt to describe the etiological factors in DAS. Some believe that children with DAS have difficulty in producing speech because of subtle *auditory (e.g., hearing, listening) deficits.* Others (Stoel-Gammon and Cooper, 1984) suggest that DAS is due to the difficulty that a child experiences in learning an adult-like language system.

Few others (Crary, 1993; Hall, Jordan & Robin, 1993, Davis, Jakeilski & Marquardt, 1998) attribute DAS to *problems in organization and sequencing abilities of speech components* (e.g., speech sounds, syllables, speech melody). A range of abilities on these skills has prompted investigators to consider DAS as a continuum disorder.

3.2.2. Developmental Apraxia of Speech as a continuum disorder

Diagnosis of DAS is typically based on the observation of a group of behavioral features (e.g. vowel errors, prosodic abnormalities etc.). There is however, no clear consensus regarding the characteristics that are crucial for identification of the disorder and the criteria for selection of participants also have not been consistent across the studies (Marquardt et al., 2001). This has led to different theoretical propositions for DAS.

DAS is considered as a neurologically based phonological disorder that results in difficulty in executing and coordinating the speech mechanism. Crary (1993) suggests that children with this disorder not only have difficulty in production of speech, but also have poor sensory-motor processing skills, which interferes with motor learning for speech that is required. Strand and McCauley (2000) define DAS as a speech disorder caused due to delay or deviance in the processes involved in planning and programming movement sequences for speech. Children with DAS experience difficulty in reaching and maintaining specific articulatory configurations, and in moving from one articulatory configuration to the next. In a study, Morley (1965) described a substantial degree of variability among 12 children with DAS. The children differed with respect to the oral movements which varied in terms of accuracy and co-ordination. The variability was attributed to severity of the disorder as well as overlap of features of apraxia, dysarthria and / or aphasia. In another study by Dewey and Kaplan (1992), children presenting with motor deficits along with poor academic skills and language deficits were studied for the characteristics in detail. Overall, four characteristic clusters were seen based on which children were divided into four subgroups. Out of the four, two subgroups presented difficulty with praxis (voluntary movement) control and sequencing tasks. This suggested a close relationship between praxis deficits and language-based skills. In a later study by Dewey (1995), children with DAS were classified into four categories based on the predominant symptoms. They included: a) conceptual disorder; b) disorder of disconnection between control centers in the cerebral cortex; c) disorder of organization of execution of movement and d) a spatial disorder.

The level of breakdown in speech processing that causes DAS is cited differently by different theories of speech production. Several speech production models (Gracco & Abbs, 1987; Crary, 1993; Van der Merwe, 1997; Caruso & strand, 1999) suggest that the origin can be found somewhere in the transition from a phonological code into articulo-motor output. That is, the phonetic planning, motor programming or motor execution could be impaired (Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Ozanne, 1995; Dodd, 1995; Van der Merwe, 1997). These views support the notion that DAS could present symptoms along a continuum (Aram & Nation, 1982; Crary, 1993; Hall, Jordan & Robin, 1993). Clinical evidences are quoted from subject reports wherein children diagnosed earlier as presenting mild articulation problem, were later during the course of remediation observed to present dyspraxic symptoms (Love & Fitzgerald, 1984; Hall, 1989).

Models of speech production by Crary (1993), Van der Merwe (1997) and Caruso & Strand (1999) explain DAS more as a continuum disorder. In the "Motolinguistic model" by Crary (1993), the oral motor and speech motor deficits in DAS are described along anterior-posterior representation in the nervous system, as a continuum from executive to planning functions respectively. It highlights that the frontal areas are important for motoric / executive aspects of speech and / or oral movement while the posterior areas are for the more linguistic and / or "planning" aspects of speech. Deficits in planning are said to be reflected as difficulty with longer, more complex sequences of speech and oral motor behavior, with the extreme end of the planning continuum reflected in poor selection and sequencing of speech elements. The impairment in planning is different from the impairment in execution which is typically reflected as poor ability to perform single movements. Further, viewing the apraxias as a group of motor disorders rather than a unitary disorder, Crary (1993) hypothesized that there is possibly more than one form of DAS, which present different types of speech / motor breakdowns depending on the component of the controlling system that is impaired. Crary (1993) drew support from the model proposed by Kent and McNeil (1987), who emphasized that there are potential information-processing steps in speech production between the selection of targets and the execution of movement.

Confirming this view further, Crary (1995) observed that disruption of different motor control processes creates clinically different motor speech disorders in children. The term developmental apart from suggesting a possible congenital basis for the disorders, also reminds of the potential disruption of more than one developmental process, thus rendering support to the impression that 'developmental apraxia of speech' could be more than a unitary disorder. If there is impairment at different levels of motor control processes in children with DAS, different clinical profiles suggesting more than a single clinical variant of developmental apraxia of speech may be evident in children with DAS, although all of these fall within the realm of *motor* speech disorder.

In agreement with the views of Crary (1995), Shriberg, Aram & Kwiatkowski (1997a) discussed the subtypes to represent one of three possible classification of DAS, they being: DAS as a unitary entity i.e., DAS manifesting independently, DAS existing with syndromes and DAS classified into subtypes. The unitary entity perspective was reported as the most prevalent conceptual approach to DAS. However, a propose broad based theoretical perspectives as that by Crary (1984; 1993) was essential in order to characterize the features of children with suspected DAS. For example, Love (1992) stated that in order to retain DAS as a viable syndrome, one should be able to define the disorder in terms of a set of obvious, widely reported and constant physical signs for definite diagnosis along with a set of less fixed symptoms. The syndrome or symptom complex perspective is based on the procedures used to identify DAS based on some criterial number of "positives" on a behavioural checklist (Shriberg et al., 1997a). The diagnostician seeks evidences of a praxis deficit on both speech and non-speech domains.

One definite and sufficient diagnostic criterion is not considered mandatory for considering DAS as a syndrome (Hermann & Opitz, 1974; Jorgenson, 1989; Gerber, 1990; Cohen, 1995). The perspective illustrated by Shriberg et al. (1997a) is based on the recommendation by Jaffe (1986) for diagnosing DAS. Jaffe (1986) stated that "Apraxia is defined by symptom cluster...Not all symptoms must be present; no one characteristic or symptom must be present; and the typically reported symptoms are not exclusive to DAS. Compounding the problem is the observation that children change over time". To further explain the subtypes in DAS, Shriberg et al. (1997a) hypothesized that different behavioural characteristics are associated with diagnostic criteria for each of the two or more subtypes of the disorder. Shriberg et al. (2003a) explain that it is more practical to envision one praxis disorder with varying severity of expression and varying topologic effects, than to envision two subtypes of apraxia, out of which only one involves stress deficits. Thus, this view is proposed to support the alternative concept of DAS as a unitary disorder of speech praxis with variable severity of expression and variable error topology.

The issue of possibility of subtypes was initially raised by Williams, Ingham and Rosenthal (1974), who failed to replicate the findings of Yoss & Darley (1974). Shriberg et al (1997a) reported that there are no well-developed typologies other than discussions on subtypes based on severity of involvement in children with suspected DAS. Hayden and Square (1993) and Hayden (1994) divided children with motor speech disorders into four subgroups reflecting differing profiles of speech-motor and cognitive-linguistic functions.

There are certain speech production theories / models (Crary, 1993; Van der Merwe, 1997) substantiating DAS as a continuum disorder. Van der Merwe's (1997) model proposed an explicit division of speech motor planning from speech motor programming. Until this time, routinely, the terms 'speech motor planning' and 'speech motor programming' were often used synonymously and interchangeably. This model clearly designated the apraxic speech errors to the motor level of impairment (Me Neil, Pratt & Fossett, 2004), describing the phases involved in the process of speech production. The theoretical framework proposed by Van der Merwe (1997), suggested the possibility of a disorder in speech motor planning to include deficits in:

- Recall of the invariant core motor plans
- Identification of different motor goals for specific phoneme
- Sequentially organizing the movements for each phoneme and a series of movements for a sequence of phonemes
- Adapting the core motor plan to phonetic context
- Inter articulatory synchronization
- Tactile-kinesthetic feedback from the periphery for adaptation (e.g. adaptation to varying starting positions)
- Centrally monitoring the efference copy
- Keeping adapted movements with in the limits of equivalence
- Systematically relaying the structure - specific motor plan subroutines to the motor programming system.

Van der Merwe (1997) explained the speech symptoms resulting from deficits in motor planning as slow and struggling speech with distortion and even apparent substitutions. Distortion, which is at times identified as the core symptom of apraxia of speech (Itoh & Sasanuma, 1984), is identified as a result of a number of deficits in the planning phase. An inability to consistently make the necessary adaptations and synchronize the movements of different articulators, centrally monitor the necessary movement parameters and to keep these parameters within the limits of equivalence, are proposed as reasons for sound distortion. An inability to plan consecutive movements at a fast rate can lead to syllabic planning and slowed temporal flow of speech. The struggle behavior often observed in apraxic speakers, is said to be the result of an inability to recall the core motor plan for the production of a phoneme or to identify and sequence of the various motor goals of a planned unit (Van der Merwe, 1997)

Contrary to Crary's motolinguistic model and Van der Merwe's model, Caruso and Strand (1999) postulated that the complete differentiation of these disorders is impossible for a variety of reasons. The first of these reasons being, the overlap in speech characteristics that is, processing deficits at different levels may result in similar speech characteristics. Second, children often exhibit motor processing deficits at more than one level. Finally, the motor processes are interactive with each other and occurs with cognitive and linguistic function when speech is formulated and produced. They highlight the importance of interaction among the different levels of the model as reasons which explain the characteristic high variability in frequency and severity of DAS.

In a study by Lewis, Freebairn, Hansen, Iyengar, and Taylor (2004), children with DAS were reported to present more severe speech and language deficit than other participants with only S (S - Speech impairment only) or SL (SL - Speech and Language impairment) groups. A continuum of disorders was observed among the siblings of the DAS probands, ranging from mild articulation disorders to more severe speech sound disorders and language disorders (Lewis et al., 2004). Several investigators also have expressed the view that DAS is not limited to the articulatory and motor aspects of speech, but encompasses other aspects of language as well (Aram & Glasson, 1979; Aram & Nation, 1982; Crary, 1982). Further research is recommended by many investigators to discern whether (or not) speech-sound disorders fall along a continuum, with DAS representing the more severe end of the spectrum.

3.2.3 Developmental Apraxia of Speech with Co-morbid Disorders

There are at least two clinical areas which are often looked into while studying any aspect of speech motor control and developmental speech disorders. They are: co-existing problems / disorders and performance loading. Crary (1993) discussed these issues extensively as they relate to children having primary developmental motor speech disorders. Crary's (1993) motolinguistic perspective emphasizes identification of disorders that co-occur with motor speech disorders. Crary (1993) suggests that the clinical management of children with suspected motor speech disorders must consider basic motor performance abilities of the speech mechanism (as well as general motor abilities), motor speech characteristics, articulation (Phonology) characteristics, language (spoken, written) abilities and potentially related academic performance and interactions among those various characteristics. It is probable that the dyspraxic children will evidence a variety of concomitant perceptual, motor, learning and language disorders. Some of the motor problems may be due to sensory weakness, poor self-image or due to failure in relating oral motor patterns.

The communication deficits of children suspected to have DAS who have at least a moderate inventory of speech sounds is reported to be similar to those of children with other speech-language disorders or neurobehavioral disorders by many investigators (Davis, Jakielski, & Marquardt, 1998; Davis & Velleman, 2000). Most individuals with DAS are reported to present with a broad range of language problems rather than with isolated speech sound disorders (Aram & Glasson, 1979; Ekelman & Aram, 1984; Square-Storer, Darley, & Sommers, 1988; Kearns, 1990; Stackhouse, 1992; Thoonen et al., 1997). Problems that may normally co-occur with DAS include problems in language, academics, motor skills, and chewing and swallowing (Hall, 2000c). According to Hodge (1994), "delays in speech onset associated with DAS are typically associated with expressive language delays and may be part of a more global language processing delay that put these children at risk for language-based social and academic problems (e.g. reading, spelling, writing)".

DAS is usually of unknown origin (Lucker-Lazerson, 2002). The assessment of this disorder by a Speech Language Pathologist (SLP) includes examination of oral speech mechanism, performance on a variety of non-speech tasks, performance on tasks which involve rapid oral movements, and an evaluation of sound errors for their consistency in type, place, and prosodic errors. Other common behaviors observed in DAS include groping, perseverative errors, and increase in frequency of errors as the length of utterance increases, and poor speech.

The term 'phonology' or 'phonological system' traditionally refers to an organizational system of rules that allows to combine sounds of a language in a meaningful manner and the term 'phonological disorder' typically implies a degree of disorganization within the rule system used to organize phonemes (Crary, 1993). Children with DAS usually exhibit phonological disorder. Some children demonstrate speech errors without disorganization in the underlying rule system. Conversely, there may be children who speak adequately but demonstrate disorganization in the underlying phonological system. Therefore, Folkins and Bleile (1990) believe that linguistic process is different from motor process of speech production. Moreover, phonological disorders are often associated with language and reading and hence, are often cited as a language-based disorder. Children with phonological disorders also exhibit poor speech intelligibility, and are also said to be at risk for acquiring reading and learning disabilities.

In line with these observations, Aram (1984) also observed that apraxia of speech, dysarthria and phonological disorder are subsets of articulation disorders in children. Children with functional articulation disorders also exhibit speech sound errors. Some articulation errors are developmental in nature (e.g. /s/, /l/, */r/)* and these sounds may not be addressed in therapy until a specific age (typically 7 or 8). The differentiation of functional articulation disorder from that of other articulatory disorders is based on the nature and consistency of speech errors. A consistent error of a sound in many environments may indicate inappropriate articulatory movements. Variations in the sound produced across environments may indicate poor phonological patterning as the articulatory movements and resulting sound production are appropriate in one context and not in the other. Such distinctions have been used to discriminate articulation and phonological disorders (Shelton & McReynolds, 1979; Shriberg & Kwiatkowski, 1988). In order to explain the variability demonstrated by individuals with articulatory errors, Crary (1993) postulated that varying degrees of severity in motor impairment may create analogous degrees of speech production deficit which in turn explains the different clusters of apraxias of speech. Motolinguistic model proposed by Crary (1993) raises the question of subtypes of children with developmental speech language disorders.

3.2.3.1 Overlapping Symptoms of DAS with Phonological disorders

Children with severe phonological disorders show poor communication abilities and reduced speech intelligibility (Locke, 1993; Cumley, 2002). These children avoid speaking situations, simplify their vocal responses, and rely more on nonverbal gestures (Kent, 1992). They may also show behavior problems, poor self-esteem, and frustration due to their expressive communication deficits (Prizant, Audet, Burke, Hummel, Maher & Theadore, 1990; Rogers-Adkinson & Griffith, 1998). Some characteristics of the phonological disorders may overlap with the characteristics of DAS, rendering diagnosis of DAS harder in a given individual. Hall et al. (1993) and Shriberg, Aram, &

Kwiatkowski (1997a, 1997b) delineated specific phonological errors such as voicing errors, cluster reduction, liquid simplification, palatal fronting, velar fronting, and stopping as being common in persons with DAS and phonological disorders. Speech-sound disorders initially diagnosed as DAS may be reclassified as phonological disorders during the course of development of a child and vice versa. In a longitudinal study, Lewis et al. (2004) studied three groups of children, children with DAS, children with isolated speech-sound disorders and children with comorbid speech and language disorders. These children were followed from pre-school to school age and assessed on measures of articulation, repetition tasks, oral motor functions and language abilities. The results indicated poorer school-age outcomes for the DAS group compared to other groups on most of the measures.

DAS being a disorder presenting deficits in motor performance, poor motor speech learning is implicit in the development of the phonological system. In general, the phonological disorders imply disorganization in speech processing at some level above the direct motor control. Although traditional definitions of DAS exclude the existence of a typical motor incoordination problem, there are a few studies, which implicate the oromotor skills and phonology in these children, strongly suggesting that subgroups exist within DAS (Rapin, 1996). Many studies have reported a high incidence of oral dyspraxia in children with DAS (Rosenbek & Wertz, 1972; Yoss & Darley. 1974; Williams, Ingham & Rosenthal, 1981; Riley, 1984).

Some investigators have attempted to explain the deficits seen in DAS and other phonological disorders based on the level of breakdown in speech processing. Mc Cauley (2003) states that Phonological Disorders (PD) are due to impairment in the cognitive - linguistic level only. On the other hand, impairment of sensorimotor planning and programming results in PD with DAS, and impairment in execution (movement of the muscles themselves) results in PD with Developmental Dysarthria. In line with these observations, Ozanne (2005) also states that DAS includes linguistic deficits (i.e., impairment in phonological planning) and motoric deficits (i.e., impairment in phonetic program assembly and execution). Similarly, Stackhouse (1992) attributed deficits seen in the speech of DAS to language and cognitive processes. Children with a phonologically based speech disorder are also reported to be at risk for reading and spelling errors because of poor phonological / cognitive processes (Gillon & Moriarty, 2007).

In general, children with moderate to severe speech impairment are frequently reported to demonstrate poor phonological awareness compared to children without speech impairment (Rvachew, Ohberg, Grawberg & Heyding, 2003; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Gillon, 2006). Stackhouse & Snowling (1992), Marion, Sussman & Marquardt (1993), and Marquardt et al. (2002) observed deficits at syllable, rhyme and phoneme levels in receptive and expressive tasks in children with DAS, thus confirming poor phonological awareness. Marquardt et al. (2002), and Gillon & Moriarty (2007) explains that poor phonological representation in DAS accounts for the poor phonological awareness, and other speech and motor planning deficits often observed in this disorder. Marquardt et al. (2002) proposed that poor phonological representation deficits (inability to perform tasks on syllable segmentation, novel phoneme identity and phoneme manipulation) in children with DAS disrupt the development of motor programs based on those representations. The hierarchical hypothesis of DAS (Velleman & Strand, 1994) also emphasized that children with DAS have difficulty representing linguistic information within a hierarchical structure, due to representational deficits in the disorder. Gillon and Moriarty (2007) hypothesized that such deficits impair children's ability to build complex linguistic structures to simple linguistic structures (e.g., to build syllables from phonemes, and phrases from words). The phonological representational deficit is reported to disrupt phonological awareness development in children with DAS, as phonological awareness tasks are dependent on access to a segmental representation of lexical items in long-term memory (Marquardt et al., 2002). The phonological representation deficit theory of DAS is thus reported as the core of the disorder in representational systems, thereby predicting phonological (reading and spelling) difficulties in those affected (Gillon & Moriarty, 2007).

3.2.3.2 Dysfluency in Children with Apraxia of Speech

There is a concern as to whether dysfluency is a symptom of dyspraxia or if stuttering and dyspraxia co-exist with each other. It is also observed that although there could be some connection between the two disorders, it is always possible that the two disorders could just be co-existing. Hammer (2002) was of the opinion that children with apraxia experience performance "overload" during therapy, since there is increased demand for complex speech motor skills which may be greater than their capacity, thus resulting in dysfluent speech. Kent (2000) observed that children who stutter are more likely to exhibit other speech and language problems than non-stuttering children. In yet another view point, Yoss and Darley (1974) proposed that stuttering as well as articulation difficulties could be differing expressions of developmental apraxia. Reviewing various studies on this issue, Kent (2000) summarized stating that the controversy continues to exist because both stuttering and apraxia are defined as a dysfunction of speech motor control.

Many investigators have observed that children who stutter or have phonological disorders may also show some features of DAS (Byrd & Cooper, 1989; Shriberg, Aram & Kwiatkowski, 1997a; McCabe, Rosenthal & McLeod, 1998). Some investigators have expressed that children who stutter are far more likely to have a phonological disorder than their non-stuttering peers (St Louis & Hinzman, 1988; Louko, Edwards & Conture, 1990; Wolk, Edwards & Conture, 1993; Bloodstein, 1995; Louko, 1995; Yaruss and Conture, 1996; Tetnowski, 1998; Yaruss, LaSalle & Conture, 1998; Louko, Edwards & Conture, 1999; Nippold, 2001). Most of the studies [(Conture, Louko & Edwards, 1993; Bernstein Ratner, 1995; Louko, 1995; Wolk, 1998; Melnick & Conture, 2000), as cited in Nippold, 2001) have established that 30% - 40% of children who stutter have a phonological disorder, in contrast to the 2% to 6% of children in the general population.

In an extensive review of studies in this area by Nippold (1990), six out of eight studies reported a higher frequency of speech sound errors in children who stuttered compared to non-stuttering children [(McDowell, 1928; Berry, 1938; Darley, 1955; Schindler, 1955; Morley, 1957; Andrews & Harris, 1964; Williams & Silverman, 1968; Seider, Gladstein & Kidd, 1982; Blood and Seider, 1981), as cited in Nippold, 2001]. Nippold (2001) observed that this warrants efforts to investigate the underlying nature of the two disorders in order to verify the possibility of a common origin.

Genetic factors are also reported to be linked to stuttering (Felsenfeld, 1997) as well as phonological disorders (Shriberg, 1997). St Louis, Murray & Ashworth, (1991), Conture et al. (1993), Wolk et al. (1993), Bernstein Ratner (1995), Paden and Yairi (1996), Yaruss and Conture (1996), Ratner (1998), Louko et al. (1999), Melnick and Conture (2000) (as cited in Nippold, 2001) support the view that children who stutter frequently demonstrate phonological disorders. Louko et al (1990) investigated for phonological processes in stuttering individuals, and found no significant difference in children with stuttering compared to non-stuttering group except for cluster reduction, although the mean number was greater for the stuttering group. Similar findings were reported by Grunwell (1982), Edwards and Shriberg (1983), and Stoel-Gammon and Dunn (1985).

3.2.3.3 Dyslexia in children with DAS

An overlap in the characteristic features of dyspraxia and dyslexia is also reported by investigators. Dyspraxia is an impairment in the organization of movements that are often accompanied by problems with language, perception and thought. Dyslexia primarily involves difficulty with learning to read, write and spell and is often accompanied by other problems such as poor organizational skills. The cluster of difficulties experienced by a person with dyspraxia may also vary widely as with dyslexia. Thoonen et al. (1997) revealed a high degree of co occurrence of DAS with learning and language problems. The disorders of dyslexia and dyspraxia are often reported to co-occur with conditions such as ADD (Attention Deficit Disorder), ADHD (Attention Deficit Hyperactivity Disorder), Asperger's Syndrome and Dyscalculia (difficulty with mathematical concepts) by various investigators (Rosenbek & Wertz, 1972; Aram & Glasson, 1979; Ekelman & Aram, 1983; Snowling & Stack house, 1983; Milloy & Summers, 1989; Lewis et al., 2004).

Lewis et al. (2004) reported that although older children with DAS generally had intelligible speech, they struggled to pronounce novel and or complex multi syllabic words accurately. The persistence of phonological difficulties in children with DAS during the early school years placed these children at risk for written language difficulties.

Phonological awareness (conscious awareness of the sound structure of spoken words) is of critical significance to reading acquisition and contributes largely to successful spelling development (Gillon, 2004). Marquardt et al. (2002) observed that children with DAS may have imprecise and / or poor access to phonological representations of spoken words, disrupting the development of motor programs based on those representations. The hierarchical hypothesis of DAS (Velleman, 1994) emphasizes representational deficits in the disorder, suggesting that children have difficulty representing linguistic information within a hierarchical structure. The phonological representation deficit theory of DAS places the core of the disorder in representational systems and predicts phonological reading and spelling difficulties in those diagnosed with DAS (Gillon & Moriarty, 2007). A breakdown in other linguistic areas such as poor word recognition and reading comprehension development other than phonology is also reported in DAS (Gillon & Moriarty, 2007).

Lewis et al. (2004) found genetic elements as factor for increased risk for dyslexia in children with DAS. They reported 86% of children with DAS had at least one family member who presented speech, language, and / or reading disorder. Genetic risk factors associated with cluster of symptoms for DAS places these children at increased risk for dyslexia (Gavan & Olson, 2003).

The ability to integrate a phonological strategy to aid spelling is reported to be particularly difficult and challenging for children with DAS. Stackhouse and Snowling (1992) and Lewis et al. (2004) found that spelling development of children with DAS was more severely impaired than their reading ability. Lewis et al. (2004) further observed that children with DAS demonstrated poor phoneme segmentation and phoneme sequencing skills, which led to poor speech production.

Identification and diagnosis of children with DAS sharing features of dyslexia and vice versa is challenging. Gillon & Moriarty (2007) summarized that the complex nature of DAS (involvement of both motor programming and planning impairments), presence of phonological awareness deficits, possible genetic risk of phonological processing difficulties and cumulative negative effect of early reading difficulty on later spelling development are factors that increase the risk of problems in development of writing skills in children with DAS.

3.2.3.4 Developmental Apraxia of Speech and Autism Spectrum Disorders

Many children with autism spectrum disorders are vocal, yet non-verbal (Seal and Bonvillian 1997). They may produce consonants, vowels and syllables, but do not use words to communicate. One of the most consistent motor findings reported in these children is the deficient performance of skilled motor gestures (DeMyer et al., 1981; Jones & Prior, 1985; Ohta, 1987; Smith & Bryson, 1994; Rogers et al., 1996). Hence, it is difficult to assess for the presence of apraxia of speech in these children (Kaufman, 2002).

Boucher (1976) and Kjelgaard and Tager-Flusberg (2001) did not find articulation deficits in children with pervasive developmental disorders (PDD). Other studies have reported high percentages of atypical vocalizations (Wetherby, Yonclas & Bryan 1989; Amoroso 1992; Sheinkopf, Mundy, Oiler & Steffens, 2000), deficits in syllable production (Wetherby, Yonclas & Bryan, 1989; Sheinkopf et al., 2000) and unusual patterns of phonological development (Wolk & Edwards, 1993; Velleman 1996; Wolk & Giesen, 2000). Wolk and Edwards (1993) and Foreman, (2001) reported restricted use of phonological contrasts and Velleman (1996) reported high levels of variability in children with PDD.

Atypical phonological development with deviant phonological processes and unexpected phonetic repertoires (Wolk & Edwards 1993; Wolk & Giesen 2000; Marili et al., 2006) as well as developmental asynchronies are also reported in children with PDD. Atypical substitutions, prosodic disturbances (Shriberg, Paul, McSweeny, Klin, Volkmar, & Cohen, 2001) and general motor deficits are also reported in children with high functioning autism (HFA) and Asperger's syndrome (Noterdaeme, Mildenberger, Minow, & Amorosa, 2002). Higher prevalence of phonological disorders and expressive language skills are reported considerably in children with HFA (Kirkpatrick & Ward, 1984).

Many studies (Hammes & Langdell, 1981; Jones & Prior, 1985; Ohta, 1987; Hertzig, Snow & Sherman, 1989; Rogers, Bennetto, McEvoy & Pennington, 1996; Williams, Whiten & Singh, 2004) have reported impairments in imitation tasks involving not only skilled motor gestures but also during the actual tool use and verbal commands. Mostofsky, Dubey, Jerath, Jansiewicz, Goldberg, and Denckla (2006) compared the praxis skills in children with Autism Spectrum Disorder (ASD) and typically developing controls. Children with ASD showed poor performance on imitation tasks, tasks on command and actual tool use, revealing that autism is associated with a generalized praxis deficit, rather than a deficit specific to imitation. This observation raised questions as to the presence of a more basic problem in motor execution / planning, visual processing, or sensory integration (Smith& Bryson, 1994; Green, Shriberg & Campbell, 2002; Rogers, Hepburn, Stackhouse & Wehner, 2003). Poor performance on imitation tasks also prompted the investigators to suggest that apraxic features are present in children with autism (DeMyer et al., 1972, 1981; Jones & Prior, 1985; Ohta, 1987; Rogers et al., 1996). Mostofsky et al. (2006) state that abnormalities in frontal parietal-sub cortical circuits which are important for acquisition (i.e., learning) of sensory representations of movement and or the motor sequence programs necessary to execute them are impaired in children with ASD.

Prosodic deficits are also reported extensively in children with autism and Asperger's syndrome (Baltaxe 1984; Eisenmajer, Prior, Leekam, Wing, Gould, Welham et al., 1996; Foreman 2001; McCann & Peppe 2003). Studies in psycholinguistics and those using imaging techniques (Penhune, Zattore & Evans, 1998; Motofsky, Goldberg, Landa & Denckla, 2000; Hardan, Kilpatrick, Keshavan & Minshew, 2003) have pointed to some neurological correlates [abnormalities such as increased brain volumes in the diencephalon, cerebral white matter, cerebellum, globus pallidus, and putamen; reduced volumes in the cerebral cortex, hippocampus, and amygdala (Herbert et al. 2003) and differences in white matter volumes bilaterally (Watkins, Dronkers & Vargha-Khadem, 2002)] and this is strongly believed to be the cause for underlying deficits in speech motor planning (in apraxics), speech motor execution in dysarthrics and phonological representation abilities in autism.

Prizant's (1996) theory states that oral motor problems affect motor planning, motor programming and motor speech, which in turn may contribute to speech and language deficits in individuals with autism. A variety of behaviors, especially poorer articulation with increase in complexity, drooling, deletion of consonants, and sequencing difficulties were demonstrated by the participants with autism, supporting the presence of an underlying speech motor processing problem. Smit (2004) reported a high co-morbidity / co-occurrence of generalized dyspraxia and autism spectrum disorders, but also reported that dyspraxia could exist by itself as a unitary entity with Autism Spectrum Disorders.

3.2.3.5 Developmental Apraxia of Speech and Other Developmental Disorders

a) Expressive Language Disorder and DAS

When a child is unable to produce phonemes or combine phonemes to produce words, their expressive language may be delayed. If this occurs, treatment should focus on both the motor-speech programming and expressive language skills. Receptive language skills are generally normal or at least much higher than expressive language skills in typical DAS group. Moore (2006) observed that expressive language disorders may also co-exist with apraxia. Cress, Sterup and Hould (2003) compared 3 - 5 year old children with severe expressive language impairments with typically developing children. They reported that 20% of the children with expressive language impairments presented with DAS. These children had poor consonant inventory and used cluster simplification, weak syllable deletion, gliding and stopping more than the control group. Weistuch and Myers (1996) studied a 5 year old child with expressive language impairment and reported the presence of verbal apraxia. Neurological, speech / language, cognitive, and play evaluations revealed that the child had good nonverbal cognitive and communicative skills. Chromosomal analysis revealed balanced translocation between first and second chromosomes.

b) Developmental Apraxia of Speech (DAS) and Developmental Co-ordination Disorder (DCD)

Diagnosis and Statistical Manual (DSM) -IV classification (APA, 2000) labels those types of motor difficulties occurring in children who have problems in developing motor co-ordination as DCD (Ayres, 1972; Portwood, 2000). The criteria for diagnosing DCD are based on performance of individuals on activities requiring perfect motor co-ordination, which is severe enough to 'interfere with academic achievement or activities of daily living' in the absence of Pervasive Developmental Disorder (PDD), Cerebral Palsy (CP), and mental retardation (Smit, 2004). The term, DAS was used to characterize the developmental problems in children with poor motor co-ordination (Miyahara & Mobs, 1995; Miyahara & Register, 2000). Hence confusions prevail in the classification and usage of terms, DAS and DCD.

Children with DCD present a wide range of dysfunctions majorly in three areas: Gross motor, fine motor, and psychosocial behaviour. Many children with DCD have soft neurological signs such as hypotonia, persistence of primitive reflexes, and immature balance reactions that interfere with gross motor development (Shoemaker, Hijlkema, & Kalverboer, 1994; Dewey & Wilson, 2001). The soft neurological signs are also part of the characteristic of DAS (Deputy, 1984). DAS children also demonstrate an awkward running pattern, fall frequently, drop items, and have difficulty imitating body positions and following 2 - to 3 - step motor commands (Smyth, 1992). Children with DCD are also reported to perform poorly in sporting events (Miyahara & Register, 2000), possibly due, in part, to their slow reaction and movement times (Henderson, Rose & Henderson, 1992) Their decreased participation in sports may result in decreased muscle force (Smyth, 1992).

Among the fine motor skills, children with DCD present history of difficulty with handwriting or drawing which are the first identifiable signs of a fine motor problem. Children with DCD are also reported to present difficulty in planning and execution of other fine motor activities such as gripping and dressing. (Smyth & Mason, 1997; Smits-Engelsman, Niemeijer & van Galen, 2001; Schoemaker, van der Wees, Flapper et al. 2001; Wilson, Maruff, Ives & Currie, 2001). Fine motor skills are also reported to be affected in children with DAS (Yoss & Darley, 1974).

Children with DCD experience problems not limited to fine or gross motor areas, but also include psychosocial problems at school. Learning disabilities and poor socialization in children with DCD is reported by few investigators (Smyth, 1992; Shoemaker, Hijlkema, & Kalverboer, 1994). DAS children are also reported to be at risk for reading and spelling disorders (Gillon & Moriarty, 2007). The characteristic features of DCD and DAS are more similar and the terms are used synonymously most of the time. There are no conscious efforts made to differentiate the disorders at present, and hence caution needs to be exercised in diagnosing and differentiating these conditions.

c) Developmental Apraxia of Speech and Down syndrome

Various studies (Ferry, Hall, and Hicks, 1975; Hamilton, 1993; Kumin & Adams, 2000) have attempted to evaluate for the presence of DAS in children with Down syndrome. Typical praxis errors such as vowel errors (Van Borsel, 1996; Layton, 2001), voicing errors (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon, 1983; Bleile & Schwarz, 1984; Van Borsel, 1988, 1996; Kumin & Adams, 2000; Stoel-Gammon, 1997, 2001), increased errors on conversational speech than single words (Farmer & Brayton, 1979; Rosin, Swift, Bless, & Vetter, 1988) and errors in prosody (Shriberg & Widder, 1990; Hesselwood, Bray, & Crookston, 1995) are reported in children with down syndrome.

Verbal apraxia affects the programming of the articulators and rapid sequences of muscle movements required for speech sound productions leading to DAS. Increased errors in speech production in persons with Down syndrome has been attributed to motor disability (Dodd, 1976), sequential processing deficits (Rosin, Swift, Bless, & Vetter, 1988), motor preplanning (Sommers, Patterson, & Wildgen, 1988), and motor planning deficits (Hesselwood, Bray & Crookston, 1995).

The review of literature on co-morbid disorders and syndrome complex indicates that the assessment and diagnosis of DAS is challenging due to the overlapping speech, non-speech and phonological characteristics in DAS and other developmental disorders. Thus, apart from proposing DAS as a continuum disorder and syndrome complex, various studies and theories in the recent past also propose that it has a close association to a linguistic base. The evidences to linguistic issues and their interaction with DAS are presented in the following sections.

3.3 Linguistic Issues in DAS

Deficits in both the motor programming and linguistic domains are implicated in DAS (Aram & Nation, 1982; Edwards, 1984). Children with DAS may show deficits in phonological representation, as demonstrated by their inability to rhyme (Marion, Sussman, & Marquardt, 1993) and to identify syllables (Marquardt, Sussman, Snow, & Jacks, 2002). Aram and Nation (1982) posited that multiple components of expressive grammar are involved in the disorder and emphasized that "...articulatory and language disorders do not simply coexist, but that both stem from a common breakdown in the selection and sequencing of both language and articulatory elements". They observed that children with apraxia presented difficulties in lexical and syntactic formulation, leading to a breakdown in speech programming which underlie both language and articulation disorders that are seen in DAS. Similar observations were also made by Paul and Shriberg (1982), Love & Fitzgerald (1984) and Panagos and Prelock (1984).

3.3.1 Nature of developing phonologies in general

Thoonen et al. (1997) investigated possible effects of syllable structure on patterns of consonant production and found that *phonological encoding* was impaired in DAS. Further, it was also seen that consonant omissions and cluster reductions occurred more frequently in syllable-final position, where as consonant substitutions were predominant in syllable initial position. Velleman and Strand (1994) claimed that syllable is crucial to understand any phonological disorder, which is part of the symptom complex of DAS. Velleman construed that there is an interplay of oral-motor skills, phonetics, phonology, learning style, and even syntax in the developmental linguistic systems of DAS.

Specific characteristics of apraxic speech support the fact that syllable context plays a predominant role in speech production. The deficits in timing and co-ordination often reported in voice-onset-time studies support this notion (Kent & Rosenbek, 1983; Ziegler & Von Cramon, 1986a). Further support is drawn from the reports of delayed transitions and problems in phasing the articulatory movements in apraxic individuals (Ziegler & von Cramon, 1985; Ziegler & Von Cramon, 1986b; Whiteside & Varley, 1998). These types of errors are explained as due to articulatory syllabic context influences, rather than due to phoneme selection and sequencing influences. Ozanne (1995) and Levelt (1989) described the role of syllabic context in the planning and programming of speech (transition from a phonologic representation to the motor programme). Marquardt, Sussman, Snow and Jacks (2002), suggested a breakdown in the ability of children with DAS to perceive 'syllabieness' and to access and compare syllable presentations with regard to position and structure.

Nijmegan et al. (2003) manipulated the syllable structure systematically in an otherwise unchanging phoneme sequence and analyzed anticipatory coarticulation, using second formant trajectories, and durational structure. The results showed stronger coarticulation in children with DAS when compared to the typically developing children. However, neither group showed systematic effect of syllable structure on the second format trajectory. Effects of syllable structure did emerge for durational structure, as the durational changes were evident in the segments of the second syllable. These adjustments were less systematic in children with DAS when compared to typically developing children. Furthermore, at the prosodic level, typically developing children showed metrical contrasts that were not recognized by children with DAS, which was interpreted as evidences for deficits in planning of syllables in children with DAS. Nijland, Maassen, Van Der Meulen, Gabreels, Kraaimaat, and Schreuder (2002) reported similar results with DAS children displaying high variability in acoustic measures of phonemically correct utterances. The inconsistency in repetitions was interpreted as evidence for immature or disturbed speech motor control.

3.3.2 Phonological development as an interactive learning process

Phonological Development is an active process. Leonard and McGregor (1991), Leonard, Schwartz, Swanson, and Frome-Leob (1987), Macken (1987), Macken and Ferguson (1983), Stoel Gammon[1] and Cooper (1984), Vihman, Ferguson, and Albert

(1986), Vihman and Velleman (1989), and many others (as cited in Velleman, 1994) have described the flexibility that characterizes children's developing phonologies. The orders of acquisition of sounds, sound combinations, and phonological rules or processes are evidences for influence of the learning style on the child's phonological system. Typically, as Velleman (1994) states, individual children demonstrate preferences for sounds, syllable shapes, or word shapes. Many children prefer the use of open ('CV') syllables (Branigan, 1976; Grunwell, 1982; Ingram, 1989). Other preferences are preluded to include syllables that require a minimum of lingual movement with in the syllable (e.g., /ti/, in which the tongue tip remains in the alveolar vicinity through out). Word shapes may be preferred based upon minimal oral-motor planning requirements. Reduplicated word, for instance, require the child to plan only one syllable, which is then repeated. Reduplication is well-documented in early child phonology [(Branigan, 1976; Schwartz, Leonard, Wilcox and Folger, 1980; Fee and Ingram, 1982; Ferguson, 1983; Schwartz and Leonard, 1983; Lleo, 1990), as cited in Velleman, 1994]. Velleman (1994) reported that typically developing children also show preferences that are based upon the order of consonantal places of articulation (e.g., labial consonant before velar consonant) or of vowel places of articulation (low vowel before high).

Clearly, phonology does not simply unfold in an innately predetermined manner as an automatic consequence of neurological and neuromuscular maturation. Stoel-Gammon and Cooper (1984), Studdert-Kennedy and Goodell (1992), and Vihman, Velleman and McCune (1994) (as cited in Velleman, 1994) have demonstrated that children's individual 'favourite babble' sounds and shapes often form the basis for their early words. Thus, the motoric preferences are based at least in part upon early phonological experiences and are instrumental in determining later linguistic preferences. Dore, Franklin, Miller, and Ramer (1976) have shown that idiosyncratic phonological forms are probably used to facilitate semantic or syntactic development.

Leonard et al. (1987), Leonard & McGregor (1991) and Leonard (1992) suggested that children with phonological disorders are more likely to demonstrate idiosyncratic phonological patterns than children whose phonologies are developing normally. Leonard (1992) suggests that this tendency may be, in part, due to children's efforts to acquire larger lexicons using less sophisticated phonological systems.

3.3.3 Hierarchical nature of phonological and phonetic systems

The developmental phonetic theories (Mac Neilage & Davis, 1990; Studdert - Kennedy & Goodell, 1992) emphasize the hierarchical nature of speech production. As consonants and vowels are not produced as separate elements in a neat series of distinct sound segments, the adjacent and even nearby segments have an impact upon each other. The mutual phonetic influences are believed to range from imperceptible articulatory changes to complete assimilation. Given that the articulators themselves relate to each other in a hierarchical fashion, some amount of phonetic influence is considered inevitable. Because of the hierarchical relationships among the articulators, elements of oral-motor planning are also said to be hierarchically related to each other. The components of each set of movements required to reach some articulatory goal are organized together into a hierarchical 'gestural score' (Studdert - Kennedy and Goodell, 1992).

The open-close movements of the mandible is said to provide the basic rhythm for the entire utterance, with articulatory modifications made with in that rhythmic 'frame' yielding what we perceive as a sequence of sound segments. This rhythmic frame provides the prosodic foundation, onto which the segmental 'content' can be built (Mac Neilage and Davis, 1990). The phonological and phonetic models, are reported to share the concepts of units at different levels with in a hierarchy organized for the processing and production of spoken language. The units are the content, and the organization provides the frame. (Velleman, 1994).

3.3.4 Speech Motor Control and Phonology

The close interaction between speech motor control and a child's emerging phonology has received increased attention in recent years (Kent, 1984). After the onset of meaningful speech, a speech pattern of repetition/ reduplication of speech movements occur. This is similar to repetitive babbling. The process of syllable reduplication observed in early stages of speech development in young children is suggestive of an interaction between speech motor pattern and language acquisition (Kent, 1984). Persistence of such reduplication may serve as a clinical sign to identify children at risk for delays in expressive language development (Ingram, 1976). Many within domain relationships are noted between phonology and a variety of other sub domains, including pragmatics (Campbell & Shriberg, 1982), syntax (Panagos & Prelock, 1982) and fluency (Caruso, Angello & Sommers, 1993).

The development of motor control of articulators plays an important role in speech development. Right from the first stage at which children produce intelligible speech, the maturation of speech motor control also continues. Children demonstrate clear indices of continuing maturation until the age of 7 years, possibly continuing up to the age of 12 years (Kent, 1984). During this developmental period, the variability of speech production decreases, resulting in stabilization of speech patterns increasingly similar to that of adult patterns (Levelt, 1989).

3.3.5 Phonological Development in DAS

One consistent characteristic of speech in children with DAS is the *inconsistency*. A large number of consonantal errors, especially (contextual) substitutions, omissions, and distortion of vowels and consonants lead to poor intelligibility of speech in DAS. There is a tendency to neutralize vowels and to stress unstressed syllables, resulting in staccato speech, or to mark phonologically unmarked consonants. This leads to the limited phonemic repertoire in children with DAS and is reflected as deviant rather than delayed phonological system. Furthermore, error rate increases with increasing length and complexity of the utterance. However, the error rate in children with DAS is reported to be much less sensitive to lexical status in contrast to that of normal children, who produce fewer errors in words than they do in nonsense words. Of all these characteristics, inappropriate stress serves as a prime diagnostic marker of DAS (Shriberg et al., 1997b, 1997c).

Shriberg et al (1997) calculated the profiles on large samples of spontaneous speech obtained from children with DAS as compared with children having speech delay. Not only were consonant, vowel, and diphthong profiles determined, but consistency analyses were also conducted by comparing word types that occurred at least twice in the sample. The conclusion is that apart from a late onset and protracted development, DAS children present no specific phonological characteristics. In summary, DAS is found to have a linguistic origin along with a neural basis.

The various aforementioned perspectives, viz, neural, neuro-behavioural, and linguistic correlates, point to numerous evidences for the notion of subgroups in DAS. It is apparent from various studies that there is an overlap among the various viewpoints, which makes it difficult to distinctly point to a definite basis for DAS. In other words, it is challenging to conclude the presence of subgroups only based on the neurological evidences, linguistic theories and models. This warrants a comprehensive assessment tool for the identification of DAS in co-occurring speech and language disorders. There are no tools available for the assessment of oral motor, oral praxis, and verbal praxis skills in Indian languages, specifically Kannada language.

4.0 Assessment and Diagnosis of DAS

Diagnosis of speech disorders requires a theoretically based judgment on the deficits underlying the impairment (Schwartz, 1992; Bradford and Dodd, 1996). This clinical procedure calls for an eclectic system of classifying speech disorders, making use of the available information with respect to symptomatology, etiology, treatment history, educational and psychological variables (Dodd, 1995; Bradford and Dodd, 1996). A diagnostic procedure that is based on the recognition of the underlying deficit, or level of breakdown (Dodd, 1995), would be most useful for research and therapeutic purposes. Oral-motor disorders are usually assessed by examining the performance of an individual on speech and nonspeech tasks. Other assessment procedures and methods most frequently used by investigators are articulation tests, process tests and more comprehensive phonological analysis procedures (Velleman, 1998).

Thoonen et al. (1997) examined speech elicitation procedure, that is, single word imitation task to assess symptoms that are relevant for the diagnosis of DAS. They also aimed to identify those speech parameters, which would yield a quantitative score to measure the severity of DAS. The most consistent finding was that there was a higher percentage of singleton consonant substitutions, omissions, distortions, and consonant cluster reductions, in DAS children than that seen in the control group. The most frequent consonant errors observed in DAS were substitutions and cluster reductions. High consonant substitution rates in DAS was also reported by Aram and Glasson (1979), Crary, Landess and Towne (1984), and Jackson and Hall (1987).

Rating the severity of dyspraxic disorder is a less addressed issue in the literature on DAS (Hall, Jordan, & Robin, 1993). The same is true in rating the severity of phonological disorder in preschool aged children (Rafaat, Rvachew & Russell, 1995). Thoonen et al. (1997) found highly significant positive correlations between severity ratings, singleton consonant and consonant clusters error rates, specifically for consonant substitutions, omissions and cluster reductions in DAS. The findings supported that error counts could be a good index for the assessment of degree of dyspraxic involvement, and can also give a quantitative and objective measure of severity. Strand (2003) also recommended characteristics such as restricted sound inventories, especially distorted vowels or a single centralized vowel sound as possible indicators of motor planning and programming difficulties in young children with DAS. There are a few standardized assessment tools available for DAS and these are presented in the next few sections.

4.1. Assessment Procedures and Measures

Various standardized procedures and measures are proposed to assess DAS in English language. These include 'The Apraxia Profile' (Hickman, 2000); 'Kaufman Speech Praxis Test' (Kaufman, 1995), 'Verbal Dyspraxia Profile' (Jelm, 2001), 'Verbal Motor Production Assessment for Children' (Hayden & Square, 1999), 'Screening Test of Developmental Apraxia of Speech' (Blakely, 2001) and others.

Assessment of children for whom the diagnosis of developmental apraxia of speech is in question should include measures of domains including nonspeech oral-motor, speech production, prosody, voice, speech perception, language, and, for older children, metalinguistic / literacy skills. Of these domains, there is some consensus on the validity of the following three segmental and suprasegmental features of DAS: (a) inconsistent errors on consonants and vowels in repeated productions of syllables or words, (b) lengthened and disrupted coarticulatory transitions between sounds and syllables, and (c) inappropriate prosody, especially in the realization of lexical or phrasal stress (ASHA, 2007).

There is very little evidence in literature regarding the presence of DAS as a unitary entity. It is observed to co occur with other developmental disorders such as phonological disorders, language disorders such as autism, ELD and others. In spite of the various protocols and standard tests, there is still a dearth of procedures to assess comprehensively the characteristics of DAS, to establish a differential diagnosis or to explore the existence of subgroups in DAS. In the Indian context, there is no standard assessment tool yet developed to meet the multicultural and multilingual needs of assessment of DAS children. Phonotactic analysis plays an important role in Indian languages, as the phonotactics is variant and distinct for each language structure. The importance of phonotactics in child phonology with a specific reference to Kannada language is discussed in the following section.

4.2 Phonotactic Assessment

Different languages have different Phonotactic patterns but there is always a trade-off among the patterns that is allowed by the language (referred to as Phonotactic constraints). The critical significance of syllable-level and word-level analysis in children (and adult) phonologies in all languages is increasingly documented over the past decades (Ferguson & Farwell, 1975; Ferguson, 1978 and Macken, 1979).

In the Indian context, phonotactics for Kannada Language has been assessed in typically developing children of different age ranges (Nayak, 1967; Hiremath, 1980). There are differences in the phonetic and phonotactic structure of Kannada as compared to English and have certain differences in the types of phonological processes. For instance, clusters in Kannada are mostly reported in the medial position both as two-sound clusters and three sound clusters. A few initial clusters are reported in Kannada by Nayak (1967), but final clusters have only been reported in borrowed English words in Kannada with a limited frequency of occurrence (Rupela, & Manjula, 2006). Gemination, which refers to the inappropriate usage of stress, is a characteristic feature reported in children with DAS. Both geminated and non-geminated clusters are found in the word medial position (Hiremath, 1980). Medial geminates are the most frequently observed clusters and are acquired as early as 12-18 months of age (Rupela, & Manjula, 2006).

At word level, disyllabic words are reported to be most common according to Hiremath (1980). However, words containing 1-6 syllables are also reported (Nayak, 1967). Final consonants rarely occur in Kannada except in borrowed English words, so open disyllables are the most commonly found word shapes, followed by trisyllables and multisyllables (Rupela, & Manjula, 2006).

4.2.1 Phonotactic issues specific to child phonology

Phonotactic patterns specific to child phonology include, development of segments by word position (development of many segments differs according to their placement with in the syllable), interactions between segmental and syllabic complexity

(As segmental complexity increases, syllabic or word complexity may decrease), the use of word-recipes (recipes determining order of the elements within a word, often ignoring the pattern of the adult form of the word), apparent regressions (reflects phonological systematization, i.e. child discover the patterns and rules of adult phonology), and the use of "illegal" Phonotactic patterns (nonadult like restrictive Phonotactic patterns). Velleman (1998) suggests the following aspects of Phonotactic patterns for consideration in assessing a child's phonology:

- Syllable and Word shapes produced by the child including constraints on allowable number of syllables per word, open versus closed syllables, and clusters in various word positions
- Word level patterns, such as harmony, assimilation, and reduplication patterns, and less commonly, dissimilation and epenthesis.
- Distribution requirements
- Word recipes, including apparent regressions
- Phrase level effects
- Prosodic factors, such as deletion of unstressed syllables.

All of the above processes are of primary importance in assessing child's phonology, especially if the child is young or his / her phonology is markedly delayed. Other factors worth noting are comprehension, grammatical morphology, mean length of utterance (MLU), apraxia, DDK and cognition. Thus, it is best not to rely on a single standardized measure to determine the existence of communication impairment (Smith &

Damico, 1995). Instead, a combination of measures should be used to probe many parameters of communicative competency. The cultural and linguistic diversity present in India warrants speech-language pathologists to consider the linguistic background of the children being assessed.

Summarizing the review of literature, it is observed that the notion of subgroups of DAS are presented by various investigators based on neurological, neuro-behavioural and linguistic substrates. The major issues substantiating the evidences for existence of subgroups of DAS include: a) Variability within DAS, b) DAS as a continuum disorder, c) Overlap of apraxic features or co-occurrence of DAS with other developmental speech and language disorders. The first issue is concerned with the variability in diagnostic considerations of DAS suggesting the possibility of subgroups within DAS. The second issue focused on DAS as a continuum disorder in terms of speech processing impairment at various levels of speech motor control. The third issue discussed DAS as a syndrome complex due to overlapping symptomatology and co-occurrence of DAS with other developmental speech and language disorders. This study focuses on investigation for subgroups in DAS by attempting to explore the presence or co-occurrence of DAS in other developmental disorders such as autism, phonological disorder and expressive language disorder. This may as well prove the functional heterogeneity in children with DAS. In order to investigate for the co-occurrence of DAS in co-morbid disorders, there is a crucial need for a sensitive and comprehensive assessment tool.

Although there are various standardized measures, it is not possible to use the same in an Indian context for young children, as they are not standardized for Indian population. The existing tools are standardized for western population and are also not sensitive in identifying the presence of apraxic features in co-occurring disorders such as autism, phonological disorders and expressive language disorder due to the overlap of symptoms. Moreover, there are no tools to assess oral motor, oral praxis and verbal praxis skills in Kannada language. Hence, the purpose of this study was to develop a protocol to assess oral motor, oral praxis and verbal praxis skills and investigate for the co-occurrence of DAS in other developmental speech-language disorders such as autism, phonological disorder and expressive language impairment.

Method

METHOD

The signs and symptoms of Developmental Apraxia of Speech (DAS) are not exclusive to participants with this disorder, but are reported to be present in participants with autism (A), phonological disorder (PD), expressive language disorder (ELD), learning disability (LD), stuttering and others. Very few studies have attempted to explore the presence and nature of praxis deficits reflecting a breakdown in speech motor control in participants with other speech and language disorders. This study attempts to investigate the existence of subgroups in DAS by means of exploring the co-occurrence of DAS in children with other speech and language disorders, viz, autism (A), phonological disorder (PD), and expressive language disorder (ELD).

Assessment of praxis deficits if any in participants with other disorders such as autism, PD, and ELD is challenging and requires a sensitive and comprehensive assessment tool. Such a tool is not available in any of the Indian languages, specifically in Kannada language. This study thus, aims to develop a protocol in Kannada language for assessment of praxis deficits in participants with other developmental disorders such as autism, ELD and PD. Secondly the study aims to investigate and explore the co-occurrence of praxis deficits if any, in oral motor, oral praxis, and verbal praxis skills in participants with other developmental disorders in comparison with that of participants with DAS.

Objectives of the study:

1) To develop a protocol for the assessment of oral motor, oral praxis and verbal praxis skills in Kannada language.
2) To assess and compare the performance of two groups of participants on oral motor, oral praxis and verbal praxis **skills:**
    A) Experimental Group I: Participants with DAS without any other co-morbid language disorder.
    B) Experimental Group II: Participants with suspected praxis deficits co-occurring with other speech language disorders:

        Group IIA - Autism

        Group IIB - Phonological disorder (PD)

        Group II C - Expressive Language Disorder (ELD).

Participants in Group II with suspected praxis deficits will be referred to in the study as suspected Apraxia of Speech (sAOS).

Participants:

Twelve participants with DAS and nineteen participants with sAOS (Autism, PD and ELD) were included in the study. All the participants were native speakers of Kannada language. Participants from groups I and II were selected from rehabilitation centers for special children, special schools and mainstream schools with Kannada as the medium of instruction. Table 2 gives the demographic details of the participants in experimental groups I and II.

Table 2: Demographic profile of participants in the experimental groups

Subject Groups	Mean Age (in years)	Male (M)	Female (F)	Total
Group I (DAS)	5.9	4	8	12
Group II (Suspected Apraxic Group)				19
A) Autism (A)	6.4	6	1	7
B) Phonological disorder (PD)	6.3	6	0	6
C) Expressive Language Disorder (ELD)	6.3	5	1	6

Participants in experimental group I, that is, Developmental apraxia were in the age range of 4.7 years to 6.3 years with a mean age of 5.9 years. Participants with Autism, PD, and ELD were in the age range of 5.2 to 7.7 years, 4.8 to 8.4 years, and 4.5 to 9.3 years, with the mean age being 6.4 years, 6.3 years and 6.3 years, respectively.

Subject selection criteria:

The following criteria were used for selection of participants in groups I and II respectively.

Inclusion Criteria:

Experimental Group I (DAS):

- Participants who were diagnosed as having DAS (without presenting signs / symptoms of any other language or speech disorder) by a qualified Speech Language Pathologist (SLP) were included. The diagnosis of DAS in these participants was based on multiple criteria adapted from literature (Stackhouse, 1992; Hall, Jordan & Robin, 1993; Ozanne, 1995; Shriberg, Aram, & Kwiatkowski, 1997a, 1997b). The diagnostic formulation was based on more than five observation or assessment sessions by the speech language pathologist. These participants were further screened for praxis deficits of speech and non-speech on a scale which was adopted from Lewis, Freebairn, Hansen, Iyengar and Taylor (2004), according to whom presence of four out of eight characteristics suggestive of a motor programming deficit is indicative of DAS. The eight characteristics listed by Lewis et al. (2004) includes (a) difficulty in sequencing phonemes and syllables, (b) trial and error groping behaviors, (c) prosodic disturbances, (d) metathetic errors, (e) decreased diadochokinetic rates, (f) consonant deletions, (g) increased errors on polysyllabic words, and (h) inconsistency in articulation with unusual error forms on both consonants and vowels. These characteristics are also endorsed as crucial diagnostic markers of DAS in children by others (Stackhouse, 1992; Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; David, Jakielski & Marquardt, 1998).

In addition, the following features were confirmed by the investigator based on the analysis of connected speech samples of participants with DAS. Presence of these features either singly or in combination were considered supportive of the diagnosis of DAS.

- Unusual error types, defined as non-developmental / idiosyncratic / deviant / atypical phonological processes

- Metathetic errors
- Prolongations
- Addition errors.
- Sequencing errors in the multisyllabic word repetition and nonsense word repetition tasks, delayed onset of speech
- Slow progress in speech therapy
- Superior receptive language abilities compared to expressive language.

- The age range of the participants was 4 to 14 years. To meet one of the inclusion criteria, lower age of four years was chosen so that the verbal corpora of children would be at least three to four words as mean length of utterance. Higher age group of 14 years was selected so that speech motor maturation would be complete by 12 - 14 years of age (Kent, 1976; Kent & Forner, 1980, Kent, 1997), as reported in typically developing children.
- Native speakers of Kannada language, a Dravidian language spoken in one of the South Indian states.
- Participants who have normal hearing ability and normal or corrected vision

Experimental group II (sAOS):

- Participants in the age range of 4 to 14 years, who were diagnosed by a qualified SLP as having co-morbid disorders such as Phonological Disorder (PD), Expressive language disorder (ELD), and Autism were included. This diagnosis was verified by the investigator using the diagnostic characteristics suggested in

DSM-IV-TR (Diagnostic and Statistical Manual for Mental Disorders) (Saddock & Saddock, 2005).

- Initially, the participants were subjected to clinical observation by the investigator and another speech language pathologist through 10 to 15 individual interactive therapy sessions. In these observation sessions, the responses of the participants were observed, analyzed, and reviewed for presence of typical features / diagnostic markers of developmental apraxia such as:

    V inconsistent articulatory errors

    V prosodic errors

    V sequencing errors

    V phonological errors such as:

        > consonant deletions,

        > vowel deviations,

        > metathesis etc

    V trial and error groping behaviour.

- Once inspected for the presence of apraxic features by the investigator and another speech language pathologist, the "screening checklist" (Refer Appendix I) was administered on these participants by the investigator. The screening checklist included 39 items / questions, which are recognized for their sensitivity in the identification of praxis difficulties. The items were scored as '1' for 'yes' ('yes' refers to presence of a particular behaviour assessed on the checklist) and '0' for 'No' ('No' refers to absence of a behaviour). A cut off score of 60 % was assigned as the ceiling limit. This referred to 60 percentage of 'pass' in the items assessed in checklist. Participants falling within the specified cut-off criteria of 60% were identified as "at risk" for praxis errors and referred to as the 'suspected apraxia of speech group'. The term 'suspected Apraxia of Speech' (sAOS) is used to refer participants whose speech and prosody-voice error patterns, performance on non-speech tasks and/or case histories are consistent with apraxia of speech (Shriberg, Campbell, Karlsson, Brown, McSweeny & Nadler, 2003a).

The presence of DSM diagnostic characteristics in the participants selected were verified by the investigator during individual interactive therapy sessions. The participants were tested individually in their respective rehabilitative centers and special schools. The diagnosis was validated based on the reports / opinions of experts in a team including a qualified SLP, psychologist, and pediatrician. The investigators diagnosis correlated with the symptoms recorded by other experts in the assessment team for each of the participants selected for the study. The salient symptoms to arrive at a diagnosis, as suggested in DSM - IV - TR criteria are as follows.

Group IIA - Autism:

> Participants should present autistic symptoms well before the age of 3.

> Participants who exhibit:

- Qualitative impairment in social interaction (marked impairment in the use of non-verbal behaviours such as eye-to-eye gaze, and failure to develop peer relationships)

- Qualitative impairments in communication (individuals having adequate speech with an inability to initiate or sustain conversation with others and stereotyped use of language / idiosyncratic language)
- Restricted repetitive and stereotyped patterns of behaviour, interests and activities such as repetitive motor mannerisms (e.g., hand flapping, twisting and others)

Group II B - Phonological Disorder (PD)

- Participants who fail to acquire speech sounds that are appropriate for age and dialect (e.g., errors in sound production, use, representation, or organization, but not limited to, substitutions, or omissions of sounds, such as final consonants).
- Speech sound difficulty that interfere with social communication.
- Participants who use phonological processes beyond the age at which they normally disappear.
- Participants with unusual idiosyncratic processes that are not observed in the normal development.

Group II C - Expressive Language Disorder (ELD)

- Participants who exhibit selective deficit in expressive language development relative to non verbal intelligence and receptive language skills [measured on standard test - Kannada Language Test (KLT) developed at AYJNIHH & RRTC, India which was a project funded by UNICEF, 1990].

- Participants who
    - have limited vocabulary, and difficulty expressing abstract or complex ideas (due to problem in content)
    - produce few spoken utterances
    - use sentences that are incomplete and ungrammatical (due to difficulties with form of the language)
    - provide stories or descriptions that are disorganized, confusing and unsophisticated (due to deficits in the use of language).

All the participants in the autism, PD and ELD groups met the following common criteria selected for the study:

- Participants selected had at least three to four words as the mean length of utterance.
- Participants selected had normal hearing and normal or corrected vision.
- Participants did not have any oral structural deficits
- All the participants were native speakers of Kannada language.

Exclusion Cnteria for groups I and II:

- Participants with any history of head injury or any other gross neurological, physical, sensory, or cognitive deficits were excluded. These deficits were ruled out based on reports from psychologist, neurologist, and occupational therapist.

- Participants with suspected or confirmed hearing impairment based on audiological screening procedures during the investigation were excluded.
- Participants with multi-lingual exposure (those who are not from a monolingual Kannada speaking family) were not included.

Exclusion criteria specifically for experimental group II A (Autism), B (PD) and C (ELD) was based on the diagnostic criteria suggested in DSM - IV - TR (Saddock & Saddock, 2005). The exclusion was also verified based on reports with documented symptoms and observations by experts such as a qualified SLP, psychologist and pediatrician in the participants' respective rehabilitation centers / special schools. The exclusion characteristics that were considered during selection of participants with autism, PD and ELD are listed below:

Group IIA - Autism:

> Participants presenting stereotypic behaviour due to associated disorders such as mental retardation and sensory impairments such as hearing or visual impairment were not included.

> Participants with severe self injurious and aggressive behaviours were excluded from the study

> Participants with non-autistic Pervasive Developmental Disorders (PDD) such as Retts syndrome, Asperger's syndrome, Childhood disintegrative disorder and PDD not otherwise specified were excluded.

Group IIB - Phonological Disorder (PD)

> Participants with co-occurring disorders such as
  - deficits in language comprehension and language expression
  - Learning disorders
  - Other developmental disorders such as attention deficit disorder and developmental co-ordination disorder were excluded.
> Participants with articulatory errors due to structural abnormalities (e.g., cleft palate), neurological disorders (e.g., dysarthria) during speech evaluation procedures and associated hearing impairment on audiological screening procedures were excluded.

Group IIC - ELD

> Participants who met the criteria for pervasive developmental disorder or mixed receptive expressive disorder were excluded.
> Participants who exhibit co-occurring disorders such as developmental co-ordination disorder, reading disorder, attention deficit hyperactive disorder (ADHD) or any other neurological deficits were excluded.
> Participants with associated hearing deficits were excluded

Test Material

Two types of test materials were developed in order to assess for the presence of praxis deficits in participants selected for the study. The test materials included:

I. Screening checklist
II. Assessment Protocol

I) Screening checklist:

The investigator compiled a *screening checklist* (Refer Appendix I) for selection of participants in experimental group II (sAOS - participants with co-morbid disorders), incorporating 39 items/questions, which were sensitive indicators of praxis difficulties. The items in the checklist were included based on various standardized measures such as Screening Test of Developmental Apraxia of Speech (Blakely, 2001); Apraxia Profile (Hickman, 2000) and others (Johnson & Jacobson 1998; Long, Bahr, & Kumin, 1998), developed for assessment of participants with DAS. The items were organized based on symptoms reported and suspected of developmental apraxia beginning from the developmental stages (speech and motor milestones) to the stage of spontaneous speech. This in turn helped to reflect on the increase in severity and errors with increasing complexity of speech which is characteristic of praxis deficit. The three major sections in the checklist included:

> Information from parents: Information regarding
  - family history,
  - developmental motor and speech milestones, and
  - play behavior.

> Observations by clinician / investigator:
  - Observations on performance of non-speech and speech tasks at word level, sentence level, and spontaneous speech.

> Items assessing:

- motor deficits, and
- sensory deficits.

The checklist developed was given to five experts in Speech Language Pathology (having minimum 5 years of clinical experience in diagnosing participants with various speech-sound disorders) for content validation. Appropriate modifications were incorporated depending on the suggestions provided by the expert group and a cut off score of 60 % was assigned to evaluate and consider the responses on the screening checklist. The items in the checklist were administered by the investigator for each subject individually with a scoring system of '0' for 'No' (absence of a particular behaviour) and T for 'Yes' (presence of a particular behavior). Those participants, who exhibited praxis deficits as per the observations made in the oral and / or verbal praxis skills on the "screening checklist", passing the specified cut-off criterion of 60% on the items in the checklist were considered at risk for developmental apraxia and selected as participants for Group II (sAOS).

II) Development of Protocol:

No standardized assessment tool is available in Kannada to assess oral motor, oral praxis and verbal praxis skills. Hence, a protocol called 'Assessment of oral motor, oral praxis and verbal praxis skills' was compiled and developed drawing support from various sources in the literature. The items were specifically designed to meet the needs of Kannada speaking individuals in the age range of 4 to 14 years. The items for the protocol were selected based on the sensitivity of the task in question to identify the features of developmental apraxia of speech as extensively and as accurately as possible. The protocol includes mostly rating scales that are different for each task. The rating scales were task oriented and were not the same across different tasks because the tasks were not comparable. The tasks included in this protocol were developed from various sources (Shipley & McAfee, 1992; Velleman & Strand, 1994; Long, Bahr & Kumin, 1998; Velleman, 2003). The details of the protocol are presented in Appendix II. It consists of the following sections:

1) Oral motor assessment tool
    A. Oral structures at rest
    B. Function of the oral mechanism for speech
2) Oral praxis assessment tool
    A. Isolated oral movements
    B. Sequential oral movements
3) Verbal praxis assessment tool
    A. Isolated verbal movements
    B. Sequential verbal movements
    C. Assessment of diadochokinetic (DDK) tasks
    D. Word level praxis assessment
    E. Sentence level praxis assessment
    F. Analysis of spontaneous speech

Description of the assessment protocol

1. Oral motor assessment protocol

The items included in this section were for the assessment of oral structures at rest and function of oral mechanism for speech as participants with DAS often show signs of oral motor deficits such as, involuntary movements, inappropriate articulatory placement and tone deficits (Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Velleman, 2003). The first section A (oral structures at rest) was adapted from 'The battery of oral-motor behavior in children' (Long, Bahr, & Kumin, 1998) with the authors' permission.

Most items from the protocol by Long et al. (1998) were included but the presentation was slightly changed. In the protocol by Long, Bahr, and Kumin (1998), the number of choices per item ranged from two to four with a non-uniform scoring procedure. This was modified to three choices per item for assessment of oral structures at rest. The participants were not required to carry out any movements on imitation or on command.

Table 3: Details regarding oral motor assessment protocol

SNo.	Oral motor assessment protocol	No. of items / tasks	Analysis / Scoring
A	Posture	11	2-point (0,1) rating scale
B	Oral structures at rest	8	3-point (0,1,2) rating scale
C	Function of the oral mechanism for speech	6	2-point (0,1) rating scale
D	Oral sensory behaviour	19	4-point (0,1,2,3) Questionnaire

Velleman (2003) emphasizes the need for assessing function of the oral mechanism for speech in terms of adequate oral-nasal distinction, ability to build up air for stops, and fricatives, and range of movement of articulators in persons with Developmental Apraxia of Speech. The assessment for function of oral mechanism for speech was carried out incorporating these items. These assessments were carried out based on investigator's observation of the participants during verbal tasks and participants were not required to perform any specific task on command.

Scoring and / or analysis

Oral structures at rest was analyzed by observing the participants during preliminary rapport building sessions and while rest of the assessment was carried out. The scoring of this subsection was adapted from Long, Bahr, & Kumin (1998) test battery. Since the source did not have a constant rating scale (varied from 2 to 4 points), a three-point rating scale was used for assessment of oral structures at rest. The scoring was done by the investigator. Function of oral structures for speech was rated by observing the speech of children. It was assessed using a two-point rating scale for which observations were made during the verbal praxis assessment.

2. Oral praxis assessment protocol

In order to assess oral praxis skills, an oral praxis protocol was compiled based on the items proposed in the scales by Blakeley (1980) and Velleman (2003). Only isolated oral movement tasks were included from both these sources and they were divided into tasks predominantly involving jaw, lip, and tongue movements.

Table 4: Details regarding the oral praxis assessment protocol.

SNo.	Oral praxis assessment protocol	No. of items	Analysis / Scoring
A.	*Isolated oral movements*		
1	Jaw movements	4	5-point rating scale (0,1,2,3,4)
2	Lip movements	5	
3	Tongue movements	8	
4	Others	2	
B.	*Sequential oral movements*	5	3-point rating scale (0,1,2)

A. Isolated oral movements

Nineteen tasks were divided into those involving predominantly jaw, lip, tongue and other movements as illustrated in Table 4. Tasks that did not fall into any of those categories such as puffing up of cheeks and clearing of throat were included under the category 'others'. Participants were instructed to imitate all movements one after the other as demonstrated by the investigator and the investigator also used a carrier phrase 'Do this' before demonstrating each movement. The task was repeated once again or a second time, if the participant performed the same inappropriately in terms of rate or accuracy or did not imitate at all.

Scoring and / or analysis

The rating scale for isolated oral praxis movements was adapted from Strand (as cited in Velleman, 2003). Scoring was based on accuracy of oral movement, rate of movement and number of different types of tactile, auditory and visual cues required to perform the movement. These cues were not explicitly explained for each item and moreover, the cues serve a more therapeutic rather than a diagnostic purpose. Hence, instead of numbers of different cues, numbers of repetitions of the task were taken into account. For this purpose and also to facilitate easier scoring, a 5-point rating scale was used instead of a 6-point rating scale as employed by Strand (1997) (as cited in Velleman, 2003). The scoring was done based on a 5-point rating scale from 0 to 4 as follows:

'4'- Movement/action is accurate and rate is appropriate

'3'- Movement/action is accurate and rate is appropriate with one repetition

'2'- Either movement/action or rate is inappropriate with more than one repetition

'1'- Both are inappropriate with more than one repetition

'0'- Child is unable to perform even with repetitions

B. Sequential oral movements

This section was incorporated to increase the complexity of the task for assessment of oral praxis deficits. It was adapted from the 'Double oromotor (non-speech) movements' section of Verbal Motor Production Assessment for Participants (VMPAC) (Hayden & Square, 1999). Movements included two sequences of oral tasks where the participants were instructed to imitate the investigator. A carrier phrase 'Do this' was given by the investigator for each task.

Scoring and / or analysis

The sequential oral movements were analyzed using two types of scores namely, 'motor control score' and 'sequential motor score' to calculate the appropriateness of movements and sequence respectively. Scoring was done as follows based on the responses given by the participants:

Motor control score (MCS):

'2'- Both movements are precise in every parameter

' 1'- One or both movements are partially imprecise in one or more parameters

'0'- One or both movements are severely imprecise in one or more parameters

Sequence maintenance score (SMS):

'2'- Completes both movements in the order stated (correct sequence)

' 1'- Completes both movements in reverse order (incorrect sequence) or adds an extra movement, or repeats a movement

'0'- Completes only one movement or completes the same movement twice

If the child did not respond due to inability to do so and not due to non-compliance or inattentiveness, then the item was marked as NR (No response) and a score of '0' was given.

3. Verbal praxis assessment tool

Verbal praxis deficits such as errors in sequencing, articulatory placement have been reported to occur frequently in participants with DAS (Hall, Jordan & Robin, 1993; Crary, 1993; Velleman, 2003). Verbal praxis skills in the participants of this study were evaluated on a protocol developed which included hierarchical tasks varying from simple to complex verbal tasks. The details are depicted in table 5.

Table 5: Details regarding verbal praxis assessment protocol

SNo.	Verbal praxis assessment protocol	No. of items/tasks	Analysis / Scoring / Measures
A.	Isolated verbal movements	22	4-point rating scale (0,1,2,3)
B.	Sequential verbal movements	7	3-point rating scale (0,1,2)
C.	Assessment of diadochokinetic (DDK) tasks	4	Rate, numbers of attempts, accuracy, and consistency
D.	Word level praxis assessment	40	• Tabulation of errors using phonological process analysis • Sequence maintenance score • Presence of groping or disfluencies
E.	Sentence level praxis assessment	10	• Percentages of consonants correct (PCC) and Percentages of vowels correct (PVC) • Sequence maintenance score • Sentence length
F.	Analysis of spontaneous speech	At least 100 words, with medial 25 words chosen for analysis	• PCC and PVC • Phonotactic assessment • Presence of groping or disfluencies

A. Isolated verbal movements

Stimuli including vowels, continuant consonants, and CV syllables with consonants that occur in initial position in Kannada were included. A total of twenty-two tasks divided on the basis of predominant use of jaw, lip and tongue movements were included in this section. Participants were instructed to imitate the investigator and a repetition or two were provided if the child was unable to perform or performed the task inappropriately.

Scoring and / or analysis

All items in this section were assessed using a 4-point rating scale similar to isolated oral movements section of the oral praxis assessment protocol. However, in the assessment of isolated verbal movements, rate of movement was not considered. Each item was scored based on accuracy of movements and whether repetitions were required to perform them. A score of '0' to '3' was given as follows:

'3'- Movement/action is accurate

'2'- Movement/action is accurate with one repetition

'1'- Movement/action is inappropriate with more than one repetition

'0'- Child is unable to perform even with repetitions

B. Sequential Verbal Movements

This section was incorporated to increase the complexity of the task for assessment of verbal praxis deficits. It was adapted from the 'Multiple oromotor-phoneme (speech) movements' section of VMPAC (Hayden & Square, 1999). Movements included double and triple verbal / speech movements comprising vowels and continuant consonant /m/. The participants were instructed to imitate the verbal movement as produced by the investigator. The sequence was demonstrated once, and if the child was able to imitate this task, the sequence was repeated three times and their imitated performance was scored.

Scoring and / or analysis

Sequential verbal movements were analyzed using two types of scores namely, 'Motor control score' and 'Sequential motor score' to calculate the accuracy and sequencing ability respectively. Scoring using a 3-point rating scale was done based on the responses given by the participants as follows:

Motor control score (MCS):

'2'- All movements are precise and in every parameter

'1'- One or all movements are partially imprecise in one or more parameters

'0'- One or all movements are severely imprecise in one of more parameters or child substitutes one phoneme for another or child does not say all phonemes

Sequence maintenance score (SMS):

'2'- Repeats all phonemes correctly

'1'- Repeats 2 out of 3 oromotor sequences correctly or repeats the oromotor phonemes 5 or 6 times

'0'- Repeats one out of 3 oromotor sequences correctly or repeats the oromotor phoneme sequence more than 6 times

If the child did not respond due to inability to do so and not due to non-compliance or inattentiveness, then the item was marked as NR (No response) and a score of '0' was given.

C. Assessment of diadochokinetic (DDK) tasks

Most assessment protocols developed for persons with DAS assess diadochokinetic tasks. DDK tasks were assessed by asking the participants to repeat syllables /pə/, /t̪ə/, /kə/, (AMR-Alternate Motion Rate) and /pət̪əkə/ (SMR-Sequential Motion Rate) as fast as they could. If they did not understand the instructions, they were given cues by tapping a finger with every syllable and progressively moving it upwards. Ten continuous iterations were considered as the best response. However, during the final data collection it was found that participants with DAS and sAOS were unable to continuously utter even 5 iterations at a given time. Hence this task was not considered for subsequent final analysis.

D. Word level praxis assessment

One hundred and eighty (180) commonly occurring Kannada words differing in syllable length and presence of clusters were compiled from a pictorial glossary in Kannada (Kumari & Mallikarjun, 1985). These words were short-listed by two speech language pathologists to sixty commonly occurring words and were then rated for degree of familiarity by 4-5 year old typically developing participants on a 3-point rating scale that was devised as follows:

'0'-1 don't know this word

' 1'-1 have heard it, but don't know what it means

'2'-1 know this word well

The 4 - 5 years age range was selected for familiarization as the age range of the participants targeted in the study included those with a lower age of 4 years. Thirty most familiar words i.e. the ones that were rated as '2' were selected from this list including five words each from disyllabic, trisyllabic and multisyllabic words with and without clusters. In order to include complex words, another list of 100 words with two and three clusters was prepared from a Kannada dictionary. These words were short-listed to thirty words by a speech language pathologist and then ten words by another speech-language pathologist. Two SLPs were involved in finalizing the list in order to improvise and validate the content of the word list. The list of words was finalized after consulting a linguist for the dialectal appropriateness of the words amongst Kannada speaking persons of Bangalore and Mysore, regions in Karnataka. All the words were arranged in a hierarchy of increasing length and presence of clusters as follows:

- Disyllabic words without clusters
- Disyllabic words with clusters
- Trisyllabic words without clusters
- Trisyllabic words with clusters
- Multisyllabic words without clusters
- Multisyllabic words with clusters

- Disyllabic words with two clusters-one in the initial and one in the medial position
- Multisyllabic words with two clusters-one in the initial and one in the medial position.

Scoring and / or analysis

The investigator uttered the list of forty words one by one and the participants were asked to imitate them. The recorded utterances were transcribed using The International Phonetic Alphabet (revised in 1993, updated 1996) by the investigator. The analyses were carried out in three ways:

a) Analysis of phonological process errors:

All the words were transcribed using the broad system of International Phonetic Alphabet (IPA) and total numbers of words produced correctly were tabulated. Definitions of phonological processes described by Stoel-Gammon, and Dunn (1985), Velleman (1998) and Pena-brooks and Hegde (2000) were used. Certain other phonological processes that are not traditionally described in literature were defined operationally and included in the analyses. The phonological processes were further classified into space, timing and whole-word errors (Velleman, 2003).This was preferred as it is said to be more sensitive in describing the phonological errors in persons with Developmental Apraxia of Speech (DAS) instead of the traditional classification of syllable structure, and syllable substitution processes. The errors were classified as follows:

- Space errors: fronting, backing, palatalization, depalatalization, and vowel deviations including vowel prolongation, vowel shortening, monophthongization etc.
- Timing errors: voicing errors, affrication, deaffrication, denasalization, consonant cluster reduction etc.
- Whole word errors: Cluster reduction, reduplication, consonant harmony, migration, metathesis, epenthesis, consonant deletions, syllable deletions.

b) Sequence maintenance score:

This score was adapted from the section, 'Oromotor production in word sequences and sentences' in VMPAC- Verbal Motor Production Assessment for Participants by Hayden & Square (1999). In this assessment, the sequence and structure of syllables within the word were analyzed. Instructions to the participants remained the same i.e. they had to repeat the words as uttered by the investigator. A three-point rating scale from 0 to 2 was employed to evaluate how the participants repeated each word. The scoring was different for disyllabic and trisyllabic or multisyllabic words as follows:

Sequence maintenance score (SMS) in disyllabic words:

'2'- Repeats both syllables in the correct order

'1'- Repeats both syllables in reverse order or adds an extra syllable or repeats a syllable

'0'- Repeats only one syllable or does not repeat any syllable

SMS in trisyllabic and multisyllabic words:

'2'- Repeats all syllables in the correct sequence

'1'- Repeats all syllables except one in the correct sequence or any one syllable in reverse order or addition of a syllable

'0'- Repeats one syllable correctly or does not repeat any syllable in the correct order

If the child did not respond due to inability to do so and not due to non-compliance or inattentiveness, then the item was marked as NR (no response) and a score of '0' was given.

c) Presence of groping, disfluencies, and weak precision in articulation:

The scoring sheet included separate columns to indicate the presence of groping, disfluencies and weak precision in articulation. These errors were defined and scored as follows:

- Groping errors: Self corrections that were silent or audible were considered as groping errors and a score of '1' was given if it was observed in a word. If groping was observed on more than one syllable of the word, it was still considered as a single occurrence.
- Disfluencies: Repetitive production of speech sounds, hesitations, and pauses were considered as disfluencies. They were calculated on the basis of numbers of

occurrences per word i.e. if disfluencies were observed on greater than one syllable of a word; it was still considered as a single occurrence and given a score of '1'.

- Weak precision of articulators: This section was included considering the presence of hypotonia in participants with DAS and sAOS. The total score was calculated per syllable. A score of ' 1' was given for every occurrence of weak precision and a high score was indicative of poor performance.

E. Sentence level praxis assessment

A list of thirty sentences with increasing lengths of syllables was prepared and a linguist was consulted to seek advice regarding the dialectal appropriateness of these sentences. These sentences were then subjected to a familiarity rating by 4-5 year old typically developing children as the lower age limit of the participants in the target groups of the study was 4 years. They rated the sentences using a 3-point rating scale that was devised as follows:

'0'-1 don't understand this sentence at all

' 1'-1 understand this sentence partially

'2'-1 understand this sentence well

Ten (10) 'most familiar' sentences with a score of '2' were selected and arranged hierarchically based on the length of sentences. Syllable length of the shortest sentence was three syllables and that of the longest sentence was twelve syllables. The participants were instructed to repeat each sentence after the investigator and each response was transcribed using the broad IPA system of transcription.

Scoring and / or analysis

The list often sentences of increasing lengths was uttered by the investigator one by one and the participants were asked to repeat them. Analyses were carried out in three ways:

a) Percentages of Consonants Correct (PCC) and Percentages of Vowels Correct (PVC) (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997):

The sentences were transcribed and the following data was excluded from analysis:

- All unintelligible and partially intelligible utterances.
- All vowels.
- All consonants in the third or more repetition of the same word if the pronunciation does not change. All consonants were scored if the pronunciation changed.

The errors in the remaining data were then identified using the following criteria:

- Dialectal changes, casual speech pronunciations and allophonic variations were not scored as incorrect.

- Any doubt about the correctness of the consonant uttered was scored as incorrect.
- Consonant deletions were scored as incorrect
- Consonant substitutions were scored as incorrect
- Partial voicing was scored as incorrect
- Distortions were scored as incorrect
- Additions of consonants were scored as incorrect

The 'Percentages of Consonants Correct' (PCC) was then calculated using the formula:

$$PCC = \frac{\text{Total numbers of consonants produced correctly}}{\text{Total numbers of consonants attempted}} \times 100$$

Using similar criteria as that of analyzing consonants in PCC, the total numbers of vowel errors were tallied from the transcribed samples and the percentage of vowels correct (PVC) was calculated as follows:

$$PVC = \frac{\text{Total numbers of vowels produced correctly}}{\text{Total numbers of vowels attempted}} \times 100$$

b) Sequence maintenance score:

This score was adapted from the scoring of 'Oromotor production in word sequences and sentences' section of VMPAC). However, VMPAC does not use greater than four-word sentences, and the protocol used in the study used as many as six words. So the scoring was divided into two, i.e. for lesser than and for greater than 3 words. A three point rating scale was provided as follows:

'2'- All the words are in the exact order or position

'1'- Sentences with < 3 words- At least 1 word is in order

Sentences with > 3 words-At least 3 of the key words are in order

'0'- Sentences with < 3 words- 0 words in order

Sentences with > 3 words-2, 1 or no key words are in order

If the child did not respond due to inability to do so and not due to non-compliance or inattentiveness, then the item was marked as NR (No response) and a score of '0' was given.

c) Sentence length:

Participants with DAS have been reported to have greater numbers of errors in motorically complex sentences, i.e., increase in errors with increasing complexity (Stackhouse, 1992; Robin, 1992; Hall, Jordan, & Robin, 1993; Velleman, & Strand, 1994; Forrest & Morrisette, 1999; Lewis et al., 2004). In order to calculate whether errors increased with increasing lengths of utterances, numbers of syllables appropriately imitated by each subject in sentences with increasing numbers of syllables were calculated.

F. Analysis of spontaneous speech

Attempt was made to record a spontaneous speech sample of at least hundred utterances from each child by indulging in general conversation about home, routine, and school. Age appropriate (Venkatesan, 2003) toys and pictures were also used in order to obtain the sample that was then transcribed for subsequent analysis. However, speech samples of participants with DAS and sAOS ranged from a minimum 25 words to a maximum 100 words. Hence, the medial 25 words were chosen for analysis.

Scoring and / or analysis

The recorded sample was transcribed using the broad system of IPA transcription The analyses were carried out in two ways. PCC and PVC scores as described under the section of sentence level praxis assessment were calculated and phonotactic analyses were also done. Phonotactics refers to the way in which syllables behave in utterances and hence reflect on errors that affect an entire syllable or word. The Phonological assessment is reported to evaluate phonetic repertoire, phonotactic repertoire and phonological patterns (Long, Bahr, & Kumin, 1998; Penabrooks & Hegde, 2000; Velleman, 2003; Rupela & Manjula, 2006).

Several researchers have hypothesized that the underlying deficit in DAS is either a sequencing deficit (Thoonen, Maassen, Wit, Gabreels, & Schreuder, 1996) or a deficit in the syllabic framework (Davis, Jakielski, & Marquardt, 1998; Marquardt, Sussman, Snow, & Jacks, 2002; Maassen, 2002; Nijland, Maassen, van der Meulen, Gabreels, Kraaimaat, & Schreuder, 2003). Davis et al. (1998) proposed 8 key characteristics of

DAS including frequent omissions, increased errors on longer units, and predominant use of simple syllable shapes. Lewis et al. (2004) found that children with DAS who were followed from preschool into school age differed from children with speech disorders at school age having more syllable sequencing errors in conversational speech than the speech-delayed children. Thoonen et al. (1996) also noted that multisyllabic word tasks were critical for differentiating CAS from dysarthria.

The phonological errors such as voicing errors, deaffrication/affrication and epenthesis were presumed to result from deficient motor planning with respect to timing (Velleman, 2003). Since many participants with apraxia have decreased awareness of the positions of articulators producing less accurate consonantal sounds, resulting in vowel deviations, they are said to present difficulties in shaping. This may lead to space errors due to overshooting / undershooting / placement errors of articulators. Others include increased omissions, decreased intelligibility on longer units (that indicates difficulty at the structural level rather than the segmental level), and also perseverative and anticipatory errors. Hence, a phonotactic analysis of the speech of participants in groups I (DAS) and II (sAOS) is essential for examining their ability to organize speech sounds in long utterances, such as words and sentences.

Phonotactic analyses were carried out using the following formulae as given by Velleman (1998) for calculation of frequency, of occurrences of various syllable shapes, word shapes, and clusters in the selected speech samples. A few examples are presented as follows:

$$\frac{\text{Number of CV syllables}}{\text{Total number of syllables}} \times 100 = \% \text{ CV syllables}$$

$$\frac{\text{Number of initial clusters}}{\text{Total number of words}} \times 100 - \% \text{ initial clusters}$$

$$\frac{\text{Number of disyllabic words}}{\text{Total number of words}} \times 100 = \% \text{ disyllabic words}$$

Similar formulae were used to calculate the percentage occurrences of the other syllable shapes (V, VC, CVC), word shapes (mono, tri and multisyllabic words) and different cluster patterns (medial geminated, non-geminated and three-sound clusters) that have been described in Appendix 1.

Procedure

Setting

The test protocol was administered in a noise free environment for individual participants. The recording was carried out either at home or clinical setting. The full battery of tasks was administered in more than one sitting, depending on the subject. Each subject was also provided with intermittent breaks of approximately every 20 minutes or whenever required based on their temperament. Total recording time ranged from 45 minutes to 1 hour per child depending on the severity of the speech disorder and the child's temperament.

Recording & Instrumentation

Prior to recording of speech sample, informed consent in writing was obtained from parents / caregivers of each participant. Audio-video recordings of speech samples of the participants on various tasks during the administration of the test protocol was carried out using a high fidelity digital camcorder Sony 703E. These recordings were supplemented with audio recordings that were done using a digital voice recorder VY-H350 with the microphone placed approximately 10 cm from the mouth of the subject. Initially, the participants were desensitized to the recording equipments by building rapport with them through general conversation and play activities wherein recordings of his / her own behaviour in the clinical setting and pictures of the child / parents taken on the camera were shown. The video recorder was placed on a tripod stand in front of the child and the investigator was seated at a 45° azimuth from the child away from the view of the camera. For participants who were too young and was distracted by the tripod placement, the investigator handled the camera manually.

Participants were suitably instructed before recording the speech samples. Instructions were specific to the task. Video recording was started whilst administration of the test battery where positive feedback and appropriate cues were given in order to elicit the speech. Whenever required, a particular task was demonstrated. In a few cases, trials were given to perform a particular task depending on the performance of the child. All participants were aware of their speech sample being recorded.

Video analysis was carried out to record even the finest movements of the articulators especially in measuring groping errors, which is a characteristic feature of participants with developmental apraxia of speech. The audio-video recordings from the disks of the digital video camera were loaded on to a Personal Computer and recorded on to a DVD (diskettes) that were then analyzed. The videos were viewed on a 17 inches wide computer monitor and analyzed by using headphones. Each child's sample was analyzed separately and scores were given in the scoring sheet as provided in Appendix I. Transcription was carried out using broad IPA transcription method. Scoring of most test items was done using a rating scale that was designed for each task separately. Those items in the protocol that had to be rated were given scores according to the instructions in the scoring sheet. Other analyses such as analyses of phonological processes, calculation of PCC, PVC and phonotactic analyses were carried out separately.

Pilot Study

No standardized protocols are available in Kannada to evaluate oral and speech motor skills in participants with DAS or sAOS. Many of the test items used in the protocol were adapted from different sources in the literature, but they were translated in Kannada and certain changes were made in the scoring The pilot study was hence necessary in order to evaluate whether the assessment protocol was effective in terms of items included and the scoring method used. The developed assessment protocol was administered on a small sample of DAS and sAOS participants as a pilot study by the investigator. The following facts were verified by conducting the pilot study:

- Appropriateness of instructions.
- Appropriateness of scoring.
- Requirement of additional tasks to evaluate oral motor, oral praxis and verbal praxis skills.
- Requirement of additional material to aid recording.
- Changes required to improve the quality of recording.

The pilot study was conducted on five participants from each of the two experimental groups (Group 1-5 and II A - 1, II B - 2 & II C - 2). The test protocol was also administered on ten age and gender matched typically developing (TD) participants in order to compare the performances of experimental groups with that of TD children. All the participants were administered the test protocol and their speech samples were audio-video recorded. Based on the results of the pilot study, it was observed that the instructions to the participants, scoring, quality of video recording, and sound levels were appropriate. No additional tasks or materials were required. Total scores were calculated based on the rating scale of the protocol and these were tabulated for statistical analysis. However no statistical tests could be carried out due to the small sample size. As statistical tests such as cluster analysis required minimum of six participants in a group, it was not possible to carry out the statistical test on the small sample size of the two experimental groups. However, the TD participants scored almost 100 % on all the sections. This showed that the tasks selected for the protocol are age appropriate.

Based on the pilot study, a few changes were made in the assessment protocol. The modification was in terms of phonological process analysis. On phonological analysis of word level praxis assessment in the pilot study, certain phonological processes that are not traditionally described in literature were noticed. They were gemination, medial consonant deletion, degemination, and syllable deletions in initial, medial and final positions. These phonological processes were operationally defined. Vowel errors such as, vowel prolongation and shortening (Pollock, 1994) were also noticed and included in the list of space, timing and whole word errors.

Reliability

Suitable measures were carried out to establish intra judge and inter judge reliability. The rating scales used in the assessment protocol are subjective and hence liable to variability. Hence, reliability check was carried out in order to establish the reliability of rating scores and that of IPA transcription. Two types of reliability measures were carried out for which two different judges (Judge 1 - the principal investigator and Judge 2 - a qualified Speech-language pathologist) were involved. The judge 2 was matched in age, gender, education, and work experience with the principal investigator. The judge 2 was explained the purpose of the study and were given appropriate training and / or instructions to carry out the assessment. The judges 1 and 2, transcribed the speech samples using IPA, rated the nonverbal and verbal imitation tasks, and identified the error types independently.

1. Inter- and intra-judge reliability: Rating scales adapted in the protocol are subjective forms of assessment that are judgment based and hence susceptible to great variability. In order to establish reliability of judgments that involved rating scales, inter- and intra-judge reliability of scoring were carried out. The judge 2 was trained to rate different items in the assessment protocol, and also given a practice trial. 30% of the data (speech samples of participants randomly selected as representative of the two experimental groups) were analyzed by both principal investigator and the second judge independently and scores were tabulated for statistical analyses. Reliability coefficient alpha was calculated and it was found to be 89%, which showed high reliability between first and second judges. Intra-judge reliability coefficient alpha was computed for the same 30% of the data after a period of three weeks from the initial assessment and it was found to be 98% for the investigator and 93% for the second judge.

2. Transcription reliability. Inter- and intra-judge reliability measures were carried out to determine reliability of IPA transcription. 30% of the speech samples from each of the experimental groups were subjected to reliability scoring. The second judge was given a brief overview of the different symbols used in IPA. Segment by segment reliability check of transcribed samples of Judges 1 & 2 revealed an inter-judge reliability of 87.13%. Intra-judge reliability was carried out by transcribing same 30% of the data from the two groups within three weeks of the first transcription. It was found to be 95.85% for the investigator and 89% for the second judge.

Friedman test was used for within group comparisons of isolated oral and verbal praxis skills further supported by Wilcoxon signed rank test. Uncorrelated equality of proportions was used to compare the percentage of persons exhibiting the various phonological processes in the two groups. Cluster analysis was used to investigate for co-occurrence of DAS in participants with sAOS, on oral motor, oral praxis, and verbal praxis skills.

Cluster analysis which is a multivariate procedure for detecting natural groupings in data was carried out and cluster tree was extracted from SYSTAT - Version 12 software. SYSTAT provides a variety of cluster analysis methods on rectangular or symmetric data matrices. It classifies sets of data into subgroups although neither the number nor members of the subgroups are known.

There are 3 procedures for clustering: Hierarchical Clustering, K-Clustering and Additive Trees. The Hierarchical Clustering procedure comprises hierarchical linkage methods. The K-Clustering procedure splits a set of data into a selected number of groups by maximizing between-cluster variation and minimizing within-cluster variation. The Additive Trees Clustering procedure produces a Sattath-Tversky additive tree clustering. In this study, Hierarchical Clustering has been chosen for analyzing the raw data as the number of clusters are automatically generated based on the association between participants, unlike K-Clustering which generates clusters based on the number of groups decided by the researcher.

Hierarchical Clustering displays the results as a tree (dendrogram). Initially, each data [Participants (in 'rows') or variables (in 'columns')] is considered as a separate cluster. SYSTAT begins by joining the two "closest" participants with similar scores as a cluster and continues (in a step wise manner) joining a participant with another participant with similar scores, a participant with a cluster (group), or a cluster (group) with another cluster (group) until all clusters that are generated fall into one unitary cluster. In this study, row wise clustering of participants was done.

Out of the different linkage methods, this study has used the single linkage method (that is, it has defined how distances between clusters are measured). Single linkage defines the distance between two participants or clusters as the distance between the two closest members of those clusters. This method tends to produce long, stringy clusters. In addition to linkage method, distance metric was used to compare clusters. Cluster analysis facilitated grouping of participants into three clusters, with each cluster constituting participants from sAOS groups (Autism, PD and ELD) who exhibited similar deficits on praxis skills, as those with DAS.

Results & Discussion

RESULTS AND DISCUSSION

The study aimed to investigate the oral motor, oral praxis and verbal praxis skills in participants with DAS in the age range of 4 to 14 years and compare their performance with chronological age matched participants diagnosed with suspected Apraxia of Speech (sAOS), with primary diagnosis of Autism, Phonological disorder(PD) and Expressive Language Disorder (ELD). A protocol was developed to assess the selected skills. A pilot study was conducted to evaluate the effectiveness of the items and the scoring method used in the protocol. Based on the outcome of the pilot study, modifications were incorporated in the protocol before its administration on the participants. The responses of the participants were rated using rating scales for oral motor, oral praxis and verbal praxis skills. The scores were statistically analyzed using SPSS - 14 and SYSTAT - 12. The various statistical procedures included: Kruskal Wallis test, Mann Whitney U test, Friedman test, Wilcoxon Signed Rank test, one-way ANOVA, Duncan's post hoc test, Uncorrelated Equality of Proportions, and Cluster analysis.

The results are presented under the following sections:

1) Oral motor skills
    - A. Oral structures at rest
    - B. Function of the oral mechanism for speech
2) Oral praxis skills
    - C. Isolated oral movements
    - D. Sequential oral movements

3) Verbal praxis skills

E. Isolated speech movements

F. Sequential verbal movements

G. Word level praxis assessment

H. Sentence level praxis assessment

I. Analysis of spontaneous speech

1) Oral motor skills

Children with DAS are often reported to show signs of oral motor deficits, hi order to assess for deficits if any in the oral motor skills of the participants, the following were assessed:

A. Oral structures at rest, and

B. Function of oral mechanism for speech.

A) Oral structures at rest

The oral structures (tongue, lips, and jaw) of all the participants were assessed for articulatory positioning or placement of oral structures, viz., lips, jaw and tongue, presence of hypotonia, and other behaviours such as involuntary movements, and drooling. The participants were not required to carry out any movements on imitation or on command. A three point rating scale varying from 0 to 2 (where 2 indicated better scores) was used to assess each of these items and the raw scores were tabulated. The raw scores were treated with BCruskal-Wallis test to determine if the difference between means of DAS and sAOS (Autism, PD and ELD) groups were significant. Table 6 and figure 1 shows the mean and standard deviation (SD) of raw scores of participants with DAS and sAOS for the assessment of oral structures at rest. Kruskal-Wallis analysis yielded a chi-square value of 4.409 which indicated no significant difference in scores obtained by participants in DAS and sAOS groups for the eight items involving the performance of lips, jaw and tongue. In other words, the skills assessed for oral structures at rest were similar in the DAS and sAOS groups.

Table 6: Mean and SD of DAS and sAOS groups for assessment of oral structures at rest.

Oral motor assessment (Maximum Score: 16)	DAS		sAOS						Chi-Square (df=3)
			ELD		PD		Autism		
	Mean	S.D	Mean	S.D	Mean	S.D.	Mean	S.D.	
Oral structures at rest	12.67	3.12	14.50	1.05	15.67	0.52	15.14	1.46	4.409

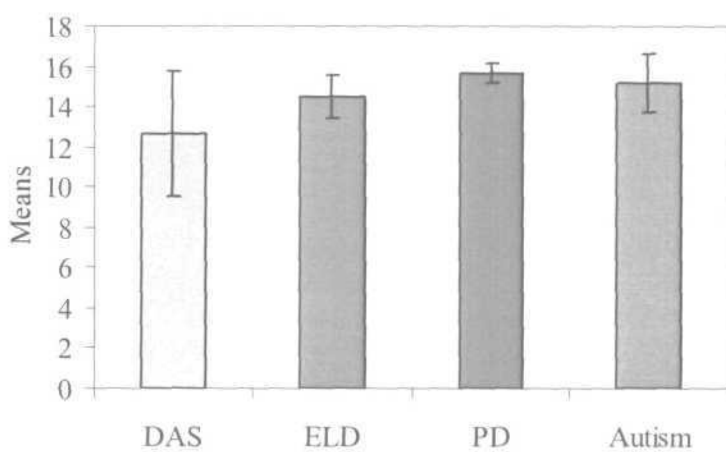

Figure 1: Mean & SD of DAS and sAOS groups for assessment of oral structures at rest.

Participants with DAS showed greater deficits in the oral structures at rest compared to those in the AOS group. This is evident from the mean values in Table 1 although there is no significant difference revealed between the groups. The mean raw scores for each item in the assessment of oral structures at rest are shown in Table 7. From table 7, it is evident that children with DAS had deficit in all the functions of oral structures. Among the twelve participants with DAS, one child (8%) showed slight jaw retraction and two (17%) of them exhibited noticeable retraction of jaw.

Table 7: Means and SD for oral structures at rest

S.No.	Oral structures at rest		DAS	sAOS		
				ELD	PD	Autism
1	Jaw alignment	Mean	1.58	2.00	2.00	2.00
		SD	0.79	0.00	0.00	0.00
2	Jaw Position	Mean	1.58	1.66	2.00	1.85
		SD	0.66	0.51	0.00	0.37
3	Lip position	Mean	1.66	1.66	1.83	1.85
		SD	0.49	0.51	0.40	0.37
4	Drooling	Mean	1.50	2.00	1.83	2.00
		SD	0.67	0.00	0.40	0.00
5	Tongue placement	Mean	1.91	2.00	2.00	2.00
		SD	0.28	0.00	0.00	0.00
6	Tone	Mean	1.58	1.66	1.83	1.85
		SD	0.66	0.51	0.40	0.37
7	Involuntary movements	Mean	1.66	2.00	2.00	2.00
		SD	0.65	0.00	0.00	0.00
8	Concomitant movements of other body parts.	Mean	1.98	2.00	2.00	2.00
		SD	0.28	0.00	0.00	0.00

In the sAOS group, none of the participants exhibited jaw protraction or retraction problems. With respect to jaw positioning, 25% of children with DAS (three participants) showed slight opening of the jaw and one (8%) child with DAS showed noticeable jaw opening. Among those with sAOS, two (33%) children with ELD and one child (14%) with autism showed slight opening of the jaw. Children with PD did not exhibit any deficit in jaw positioning. Participants with sAOS groups showed deficit in lip positioning similar to participants with DAS. Among sAOS groups, 33% of children with DAS (4 of 12), 33% of children with ELD (2 of 6), 17% of PD group (1 of 6), 14% of autistics (1 of 7) obtained poor scores in lip positioning (slightly protruded or retracted lips) indicating the presence of hypotonia of the lip.

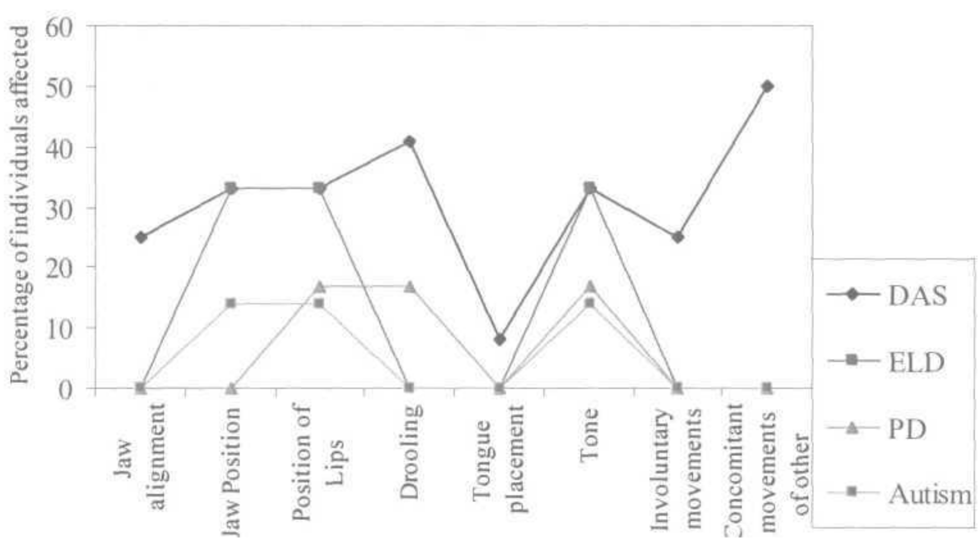

Figure 2: Percentage of individuals with deviant behaviours on assessment of oral structures at rest.

When assessed for tongue placement, one (8%) child with DAS showed improper tongue placement by placing the tongue on the bottom of the lower lip indicating hypotonia of tongue. However, none of these children showed tongue thrust. Amongst all the items assessed, participants with DAS showed least scores when assessed for drooling behaviour. Four children (33%) with DAS presented with drooling but showed self monitoring ability by trying to swallow it. Where as one (8%) DAS participant showed noticeable drooling with out any self monitoring ability to swallow it. One (16%) PD participant also showed slight drooling but could swallow. The presence of drooling, improper jaw (open jaw), lip (retracted lips) and tongue placement indicated presence of mild hypotonia in around 33% of children with DAS. While in sAOS group, 33% of children with ELD (two participants), 17% of children with PD (one participant) and 14% of autistics (one participant) showed presence of mild hypotonia in jaw and lips which is indicated by the open jaw and retracted lips similar to DAS group. Involuntary movements and simultaneous movement of body parts with oro-structural movements were observed in 25% (three participants) and 50% (six of twelve participants) of individuals with DAS, respectively.

Developmental apraxia is often reported to accompany oral apraxia, hence not only speech but other aspects of oral motor co-ordination and sequencing are also reported to be affected (Robin, 1992; Velleman, 2002). Davis and Velleman (2000) reports the presence of drooling, late development of motor skills and overall oral motor in co-ordination in children with praxis deficits. Although the extent of oral motor deficits in children with DAS varies, the major problem observed in DAS was drooling followed by improper placement of jaw, lips and tongue. This could be attributed to mild degree of hypotonia and involuntary movements seen in almost 33% of children with

DAS. Consequently, DAS group is shown to exhibit poor oral motor skills compared to the sAOS group. Thus, the findings of this study support the earlier findings showing the presence of oral motor deficit in participants with DAS.

Prizant (1996) reported that oral motor problems affecting motor planning, motor programming, and motor speech may be a factor in the speech and language deficits of individuals with autism. The scores obtained by autistic participants suggest mild hypotonia due to open jaw and retracted lips. PD group also showed deficits with retracted lips, and presence of drooling. In the ELD group, mild hypotonia was observed in jaw (open jaw), and lips (retracted lips). It is notable that concomitant movements of oral structures with other parts of the body had negligible effect on speech production in sAOS groups. However, there were evident oral deficits in participants with sAOS. The results should be interpreted carefully because of the limited subject number and variability seen with in each of these groups as not all the participants with sAOS are equally affected on all the items assessed. There is dearth of studies investigating deficits in function of oral structures in both DAS and sAOS groups. Yet, the findings of this study show varying degree of oral problems in both DAS and sAOS groups when oral structures were assessed at rest, with DAS group showing greater deficits than sAOS participants. The insignificant difference in performance between the groups with DAS and sAOS are indicative of co-occurring oral motor deficits in sAOS groups similar to the oral problems observed in participants with DAS.

To further determine the overlap and co-occurrence of praxis deficits in sAOS groups and to see the number of participants from sAOS groups who showed similar oral motor errors like those observed in participants with DAS, cluster analysis in SYSTAT 12 was carried out. This analysis generated three clusters supporting significant co-occurrence of praxis deficits in participants with sAOS for assessment of oral structures at rest as shown in Figure 3. Each cluster constituted participants from sAOS groups who exhibited similar oral motor issues as the DAS group on items assessed for oral structures at rest, thus indicating the co-occurrence of deviant praxis behaviour in sAOS groups comparable to DAS. The number and percentage of participants clustering under each group is tabulated in Table 8. The maximum score for oral motor assessment was 16, which indicates normal performance of an individual with out any oral motor issues. Any score lesser than 16 indicates oral motor problems in the individual. The score ranges, 8 - 13, and 14 - 15 shows grouping of participants with oral motor deficits. These score ranges were obtained based on association of participants exhibiting similar scores from cluster analysis.

Table 8: Number (No.) and percentage (%) of participants clustered from DAS and sAOS groups for Oral motor praxis skill.

Clusters	Score range (Maximum Score: 16)	DAS		ELD		Autism		PD	
		No.	%	No.	%	No.	%	No.	%
I	8-13	6	50.00	3	50.00	1	14.28	0	0
II	14-15	2	16.66	2	33.33	2	28.57	2	33.33
III	16	4	33.33	1	16.66	4	57.74	4	66.66

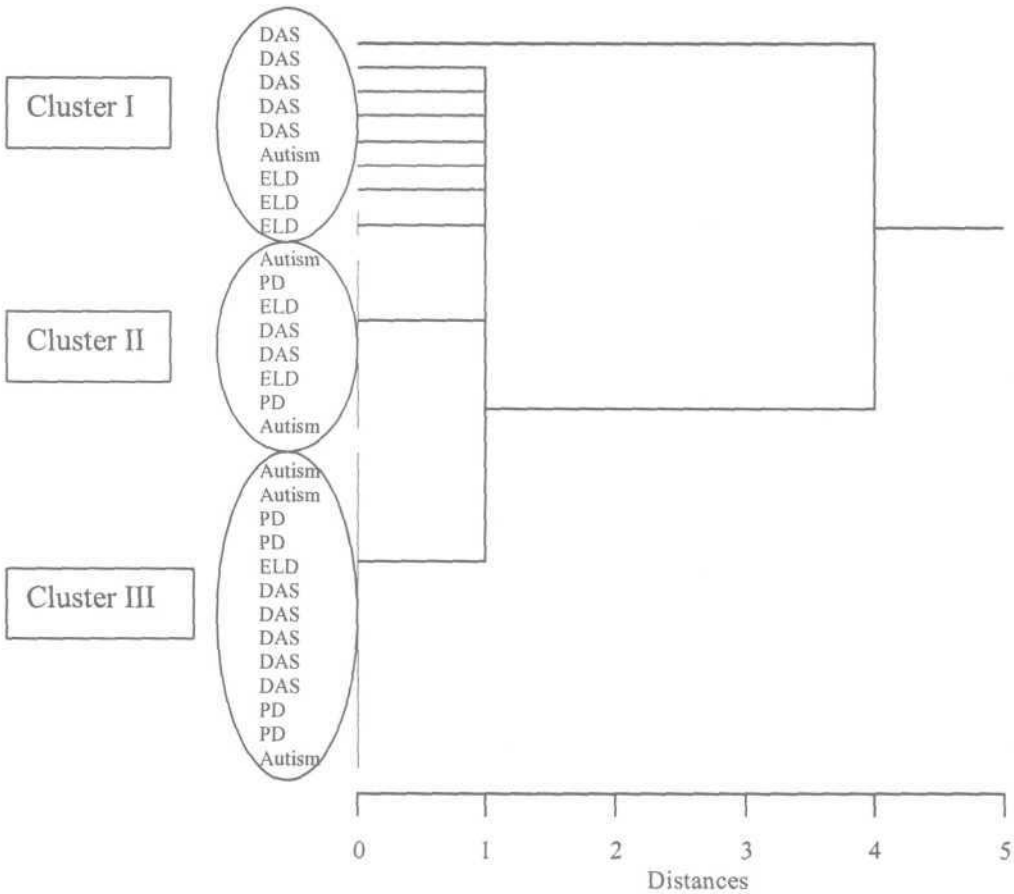

Figure 3: Cluster tree depicting the clusters I, II and III for oral structures at rest.

Cluster I shows clustering of participants who had major oral problems in terms of abnormal alignment of oral structures, tone deficits and involuntary movements of oral structures at rest. It shows three (50%) participants with ELD and one (14.28%) participant with autism exhibiting similar oral motor issues like six (50%) participants with DAS. Whereas, none of the participants with PD were grouped under cluster I suggesting that children with phonological disorder do not show severe deficit in oral structures at rest.

Cluster II shows clustering of participants who had a mild oral deficit in one or two tasks on oral structures but showed a better performance than cluster I. It is seen that two (33.33%) participants with ELD, Autism (28.57%) and PD (33.33%) had mild oral motor deficit either with respect to abnormal tone or alignment of oral structures or involuntary movements similar to one (16.66 %) participant with DAS.

Cluster III in Table 8 shows clustering of participants with best performance on this task assessing oral structures at rest, attaining the maximum score of 16. It reveals that one (16.66%) participant with ELD, four (57.74 %) participants with autism and four (66.66%)participants with PD do not have any deficits in function of oral structures similar to four (33.33%) of the participants with DAS. This shows that participants from each of the 4 groups do not show either any involuntary movements or abnormal tone in their oral structures at rest revealing absence of deficit or deviant oral motor behavior. While majority of participants with ELD (83%) have deficit in oral structures at rest, around three (43%) of the participants with autism show oral motor deficit similar to those with DAS.

In order to check for significant difference if any in the performance of participants with DAS and sAOS grouped in the 3 clusters, 'one-way ANOVA' was employed. The mean and standard deviation (SD) for the clusters I, II and III are shown in table 9.

Table 9: Mean and Standard Deviation (SD) of three clusters for Oral Structures at rest.

Clusters	N	Mean	SD
I	7	9.5	2.99
II	10	14.8	0.42
III	14	16.0	0.00

Group comparison using 'One-way ANOVA revealed a significant difference in the performance scores between participants with DAS and sAOS in cluster I and other two clusters II & III [$f(2) = 50.336$, $p<0.01$]. But Duncan's post hoc analysis did not reveal any significant difference between clusters II and III. The findings suggest that the participants with ELD and autism grouped under cluster I performed poorly on oral motor tasks showing significant oral motor deficit similar to participants with DAS, while PD children did not show significant oral deficits. The results suggest that the performance of participants with ELD and autism from suspected apraxic group is similar to participants with DAS to certain extent. The findings are suggestive of co-occurrence of deviant oral motor behaviour in the suspected apraxic group specifically in participants with ELD and autism than PD, in terms of severity.

Overall, the major deficit noticed in sAOS groups was open mouth posture with deficits in jaw and lip positioning, which could be due to hypotonia of a mild degree that was observed in around 33% (2 of 6) of participants with ELD, 14% (1) of autism and 17% (1) of participants with PD. Other behaviours such as drooling, involuntary movements and presence of concomitant movements of oral structures with other parts of the body were less prevalent and were not so severe as to affect the production of speech significantly. Although participants with DAS demonstrated poor oral skills than the sAOS, some participants with sAOS also showed similar oral problems as the DAS group. This trend seen in sAOS groups which is similar to participants with DAS suggests the co-occurrence of oral motor deficits in participants with sAOS as well.

B) Function of the oral mechanism for speech

The function of oral mechanism for speech was rated based on the observations drawn from the verbal praxis assessment of all participants. Observations included tests for adequacy of intra-oral breath pressure for stops, air build-up and precision of fricatives, oral-nasal distinction, and range of movement of lips, tongue and jaw. The participants were not required to perform any task on command. The items in this section were analyzed and rated on a 2-point scale (0 to 1, with 1 revealing adequate performance) to obtain the raw scores. The raw scores were subjected to statistical analysis using Kruskal-Wallis test to arrive at chi-square values. Table 10 and figure 4 shows the group mean performance of participants in the assessment for function of oral mechanism for speech.

Table 10: Mean, SD and chi-square values for function of oral mechanism for speech

Oral motor assessment (Maximum score: 9)	DAS (N: 12)		sAOS						Chi-Square (df=3)
			ELD (N: 6)		PD (N: 6)		Autism (N: 7)		
	Mean	S.D	Mean	S.D	Mean	S.D.	Mean	S.D.	
Function of the oral mechanism for speech	3.25	1.48	4.33	0.82	4.83	0.75	4.43	0.98	6.549

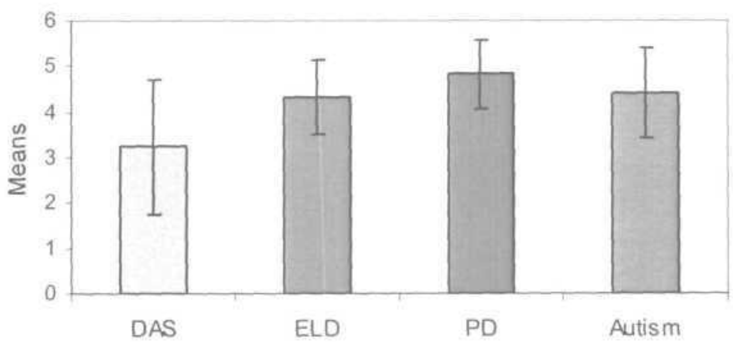

Figure 4: Means and SD for function of oral mechanism for speech

Participants in DAS and sAOS groups did not differ significantly from each other and their raw scores ranged from 0 to 9. Although the groups did not show a significant difference, individual variations were observed. Raw scores for participants with DAS ranged from 1 to 6 and the scores ranged from 3 to 5, 5 to 7 and 3 to 6 for groups with ELD, PD and autism in sAOS groups, respectively. From the mean values in table 10, it can be inferred that DAS group demonstrated poor oral functions compared to those with ELD, PD and Autism. Amongst sAOS group, autistics performed poorer followed by children with ELD, compared to the PD group. Table 11 and figure 5 show the mean scores of groups with DAS and sAOS for individual functions of the oral mechanism.

Table 11: Mean and SDs for individual functions of oral mechanism for speech

S.No.	Function of oral mechanism for speech		DAS (12)	sAOS ELD (6)	sAOS PD (6)	sAOS Autism (7)
1	Intra oral air build-up for stops	Mean	0.55	1.00	1.00	0.85
		SD	0.38	0.00	0.00	0.37
2	Air build-up for fricatives	Mean	0.41	0.66	0.83	0.71
		SD	0.51	0.51	0.40	0.48
3	Oral - Nasal Distinction	Mean	0.45	1.00	1.00	1.00
		SD	0.25	0.00	0.00	0.00
4	Range of lip movement	Mean	0.51	0.00	0.83	0.42
		SD	0.38	0.00	0.40	0.53
5	Range of jaw movement	Mean	0.61	1.00	1.00	1.00
		SD	0.28	0.00	0.00	0.00
6	Range of tongue movement	Mean	0.50	1.00	0.83	0.42
		SD	0.52	0.00	0.40	0.53
7	Precision of lip movement	Mean	0.16	0.00	0.16	0.00
		SD	0.38	0.00	0.40	0.00
8	Precision of jaw movement	Mean	0.08	0.33	0.16	0.14
		SD	0.28	0.51	0.40	0.37
9	Precision of tongue movement	Mean	0.00	0.33	0.16	0.00
		SD	0.00	0.51	0.40	0.00

It is evident from table 11 that participants with DAS obtained poorer scores in all test items assessing oral function. Air build up and precision for the production of fricatives and precision of lip, tongue and jaw movements was most affected in participants with DAS followed by range of movement of tongue and lip and intra oral breath pressure for stops. Figure 5 depicts the percentage of individuals affected across all groups.

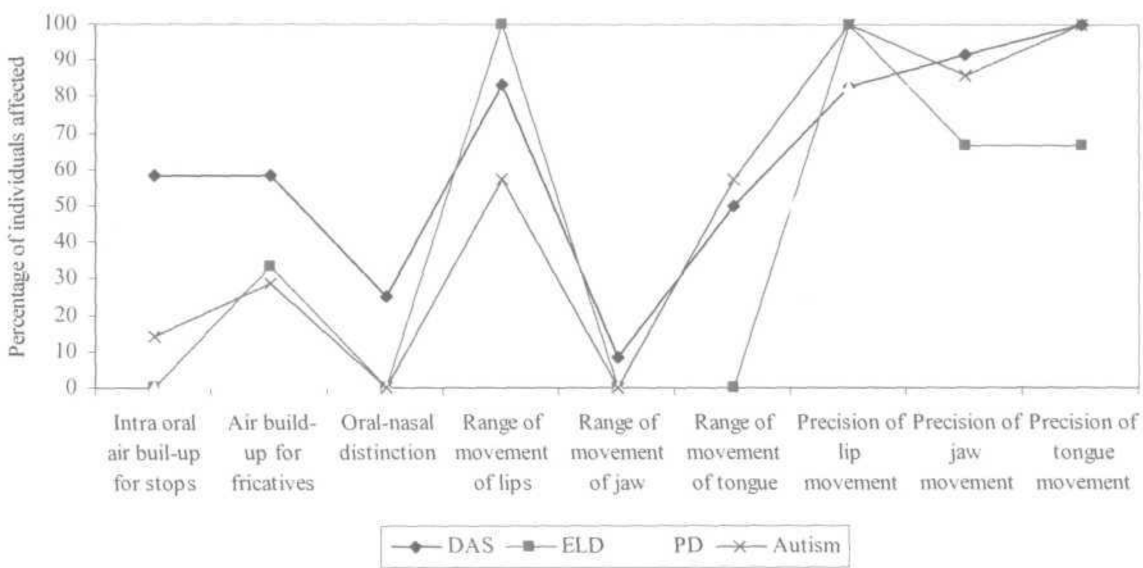

Figure 5: Percentage of participants affected in 'function of oral mechanism for speech' tasks across DAS and sAOS groups.

In more than 80% of children with DAS, precision of lip, tongue and jaw movements was affected the most. Around 58% of DAS children exhibited poor precision and inadequate intra oral air-build up for production of fricatives. Since fricatives require greater precision of articulators than stops, they are considered as difficult sounds to produce. Inadequate intra-oral air build up for stops and poor range of tongue, lip, and jaw movements in DAS is indicative of mild hypotonia in oral structures. 25% of children with DAS showed poor oral nasal distinction indicating poor velopharyngeal incompetence. Predominance of velopharyngeal incompetence and nasalized speech in DAS is also reported by many investigators (Yoss & Darley, 1974; Aram & Glasson, 1979; Bowman, Parsons, & Morris, 1984; Parsons, 1984; Hall, Jordan, & Robin, 1993). Velleman (2003) considers nasality as a sign of dysarthria.

Compared to the DAS group, the sAOS groups showed poor precision for lips, tongue and jaw movements in 90% of participants with ELD, PD and autism. This was followed by inadequate intra oral air build up for fricatives [ELD (33.3%), PD (25%) and autism (28.6%)] which is similar to DAS group. Table 11 reveals that range of articulatory movements was the next most affected skill in the sAOS groups. Range of lip movements was affected the most in ELD group (100%). Besides, participants with PD (17%) and autism (57%) exhibited inadequate range of movements of lips and tongue. This was probably due to the presence of hypotonia in the oral structures that in turn led to the limitation of oral movements in sAOS groups. The most affected items in sAOS groups were similar to that observed in participants with DAS. This suggests that there is co-occurrence of deficits in functions of oral mechanism for speech in participants with sAOS similar to DAS group.

In order to depict the overlapping characteristics and investigate for the co-occurrence of oral motor deficits in sAOS groups like in the DAS group, the raw scores of participants in the two groups were subjected to cluster analysis. Cluster analysis was employed to determine the presence of clusters or grouping of participants from the two groups, viz, DAS and sAOS, based on their performance scores. Table 12 and figure 6 depicts the three clusters with grouping of participants from sAOS, who exhibited similar errors on functions of oral mechanism to that of participants with DAS.

Table 12: Number (No.) and percentage (%) of participants clustered from DAS and sAOS groups for assessment of oral functions

Clusters	Score range (Maximum Score: 9)	DAS		ELD		Autism		PD	
		No.	%	No.	%	No.	%	No.	%
I	1-3	8	66.66	1	16.66	1	14.28	0	0
II	4-5	3	25.00	5	83.33	5	71.42	2	33.33
III	6-7	1	8.33	0	0	1	14.28	4	66.66

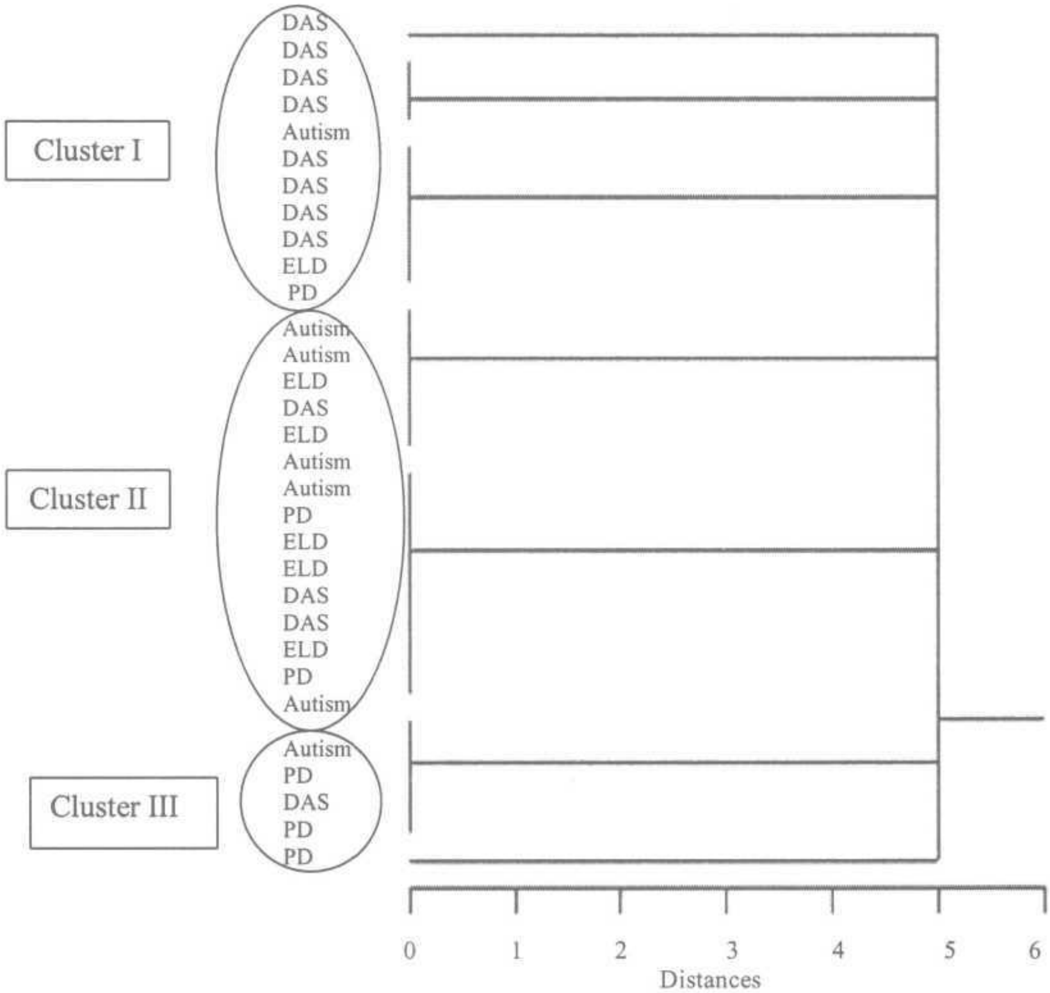

Figure 6: Cluster tree depicting the Clusters I, II and III for assessment of function of oral structures.

Cluster I in Table 12 shows clustering of participants with poorest performance on assessment of functions of oral structures with scores ranging from 1-3 for a total of 9. It is seen that one (16.66%) participant with ELD and one (14.28%) participant with autism exhibited similar errors like the eight (66.66%) participants with DAS grouped under cluster I. None of the participants with PD were grouped in cluster I. This shows that participants with ELD and autism (sAOS) have performed poorly and similar to DAS on tasks assessing function of oral mechanism, thus supporting severe oral motor issues in sAOS groups. However, only one child with ELD and autism showed severe oral function deficit. Majority of these participants were clustered in cluster II.

Cluster II shows grouping of participants who had moderate difficulty in performing approximately four to five of nine tasks (around 50%) in the assessment of function of oral structures, consequently showing a poor performance compared to cluster III. It is evident from table 12 that five (83.33%) participants with ELD, five (71.42%) participants with autism and two (33.33%) participants with PD had mild difficulty in performing functions of speech mechanism similar to two (25 %) participants with DAS, thereby suggesting the presence or co-occurrence of oral motor issues in sAOS groups like in DAS.

Cluster III shows clustering of participants who performed relatively better and exhibited lesser errors than those in clusters I and II but still were not able to attain the maximum performance score of 9. Table 12 reveals that one (14.28%) participant with autism and four (66.66%) participants with PD performed similar to one (8.33%)

participant with DAS. None of the participants with ELD were grouped in this cluster. These findings reveal that maximum participants with PD have performed better on tasks assessing oral function while participants with ELD and autism show major oral motor deficits similar to those with DAS. The results are similar to the findings on assessment of oral structures at rest reported in the previous section.

In order to check for significant difference in the performance of participants with DAS and sAOS in the 3 clusters, 'one-way ANOVA' was employed. The mean and standard deviation (SD) for the clusters I, II and III are shown in table 13.

Table 13: Mean and Standard Deviation (SD) of three clusters for function of oral mechanism for speech.

Clusters	N	Mean	SD
I	10	2.50	0.71
II	15	4.60	0.51
III	6	6.17	0.41

The results of Duncan's post hoc analysis revealed significant difference between clusters I, II and III [f (2) = 85.389, p<0.01]. There is significant difference in the performance of participants with DAS and sAOS groups clustered under three. DAS and sAOS participants in Cluster I showed greater errors on function of oral mechanism for speech followed by those in cluster II with comparatively better scores which in turn is followed by cluster III with highest scores for a total of 9. The point to be noted is that the participants under cluster III did not attain the maximum possible score indicated for normal performance, suggesting the presence of oral motor issues in sAOS groups as well as DAS. It is inferred that participants with ELD and autism in sAOS groups show co-occurrence of oral motor issues similar to participants in DAS group. Participants with PD seem to show lesser degree of severity in oral motor deficit.

Both groups with DAS and sAOS were not able to build up intra oral air pressure adequately for fricatives. This could be due to the fact that production of fricatives requires more precise transition of articulators and an adequate oral motor co-ordination for air build-up. Moreover fricatives are considered to be acquired later compared to stops (Zisk & Bialer, 1976; Bleile & Schwarz, 1984). The difficulty in production of fricatives in sAOS groups is similar to that of DAS.

The reduced range and precision of tongue, lip and jaw movements exhibited by children with DAS and sAOS may be due to hypotonia in oral structures. Imprecision due to hypotonia is cited as a sign of dysarthria. Morley (1965) considers overlap of features between apraxia and dysarthria and / or aphasia, but not different forms of apraxia. Dyspraxic children are said to experience a degree of dysarthria and / or general motor in-coordination (Deputy, 1984). Rosenbek and Wertz (1972), in their study, found that 26 % of the children with DAS had a combination of apraxia and dysarthria, while 16% had a combination of apraxia, aphasia and dysarthria. Velleman (ASHA, 2007) reports that approximately 10% of children with autism have primarily dysarthric component and co-existing symptoms of both apraxia and dysarthria in 37.5% of children with autism. The results of Marili, Andrianopoulos, Velleman & Foreman (2004) study support a probable underlying motor-related problem consistent with apraxia of speech and/or dysarthria in a subset of individuals with Pervasive Developmental Disorder. In addition, Marili et al.

(2004) found a statistically significant correlation between the number of dysarthric-apraxic symptoms that coexisted in autistic participants. They reported that apraxic and dysarthric symptoms appear to co-occur more often in this population. Also, there are studies which quote the presence of dysarthria in children with phonological disorder and the processing impairment in this group is attributed to execution difficulties (Mc Cauley, 2003). Still it may be immature to conclude the presence of associated dysarthric component in these groups due to limited number of subjects.

While the sAOS groups were not affected much in terms of functions of oral structures at rest, varying degrees of problems were observed in participants with DAS. Function of the speech mechanism in terms of intra-oral breath pressure, velopharyngeal mechanism, precision and range of articulatory movements were affected most amongst the skills tested in DAS. In sAOS groups, intra oral breath pressure, precision and range of movements of tongue and lips were the most affected.

From the results in the section on oral motor assessment, it is notable that children with DAS have more oral motor issues in terms of structure and function. Still, there is no significant difference revealed in the performances between children with DAS and those in sAOS groups in either of the domains. It should be noted that in both DAS and sAOS groups, not all the children showed oral motor deficit. There are variations in terms of number of participants affected in each item which is evident from the percentage scores and standard deviation values. Based on these comparative findings in groups with DAS and sAOS, co-occurrence of oral motor deficits in participants with sAOS can be inferred. Further sections reports on the contribution of these co-occurring oral motor issues on oral and speech praxis in children with sAOS as compared with the DAS group.

2) Oral praxis skills

Oral praxis deficits have been cited as characteristic features in children with DAS when there is accompanying oral apraxia (Hall, Jordan & Robin, 1993; Crary, 1993; Velleman, 2003). Oral praxis skills were assessed in the two groups of participants with DAS and sAOS on the following two tasks:

A. Isolated Oral Movements

B. Sequential Oral Movements

A) Isolated oral movement tasks

In this task, the participants were asked to imitate the oral movements as performed by the investigator. The oral movements were rated on a 5-point rating scale from 0 to 4 depending on accuracy and rate of the responses, and also the number of repetitions required to elicit the behaviour as follows;

'4'- Movement/action is accurate and rate is appropriate

'3'- Movement/action is accurate and rate is appropriate with one repetition

'2'- Either movement/action or rate is inappropriate with more than one repetition

'1'- Both are inappropriate with more than one repetition

'0'- Child is unable to perform even with repetitions

The raw scores were subjected to statistical analysis using Kruskal-Wallis test in order to find the main effect of groups. Since there was significant difference between the groups, pair-wise analysis was done using Mann-Whitney test to find the groups that differed significantly. Table 14 and figure 7 depicts the overall Mean, SD and chi-square values for the isolated oral movements. As evident from table 14 and figure 7, the groups significantly differed from one another at .001 levels of significance. For a total score of 76, raw scores for participants with DAS ranged from 15 to 50, and those with ELD, PD and autism ranged from 39 to 49, 17 to 46 and 13 to 41, respectively. Mann Whitney test revealed that ELD significantly differed from groups with DAS, autism, and PD. Autism group exhibited greater oral praxis problems in isolated oral movements than participants with PD and ELD in sAOS groups and DAS group. The performance of autism and PD did not differ significantly from participants with DAS. ELD exhibited relatively better scores than participants with PD and autism in sAOS groups.

Table 14: Mean and SD for isolated oral movements assessing oral praxis skills

Oral Praxis assessment (Maximum Score: 76)	DAS (N: 12)		sAOS						Chi-Square (df=3)
			ELD (N: 6)		PD (N: 6)		Autism (N: 7)		
	Mean	S.D	Mean	S.D	Mean	S.D.	Mean	S.D.	
Isolated oral movements	33.80	10.19	44.53	3.52	36.53	10.68	27.20	10.66	11.543***

***p<.001

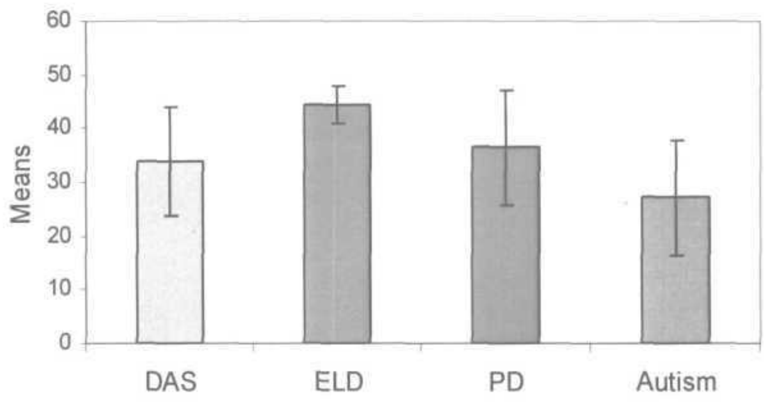

Figure 7: Mean and SD for isolated oral movements

All the isolated oral movements were divided into predominantly jaw, lip, and tongue movements. Those movements that did not fall into any of these categories such as puffing up of cheeks and clearing of throat were included under the category 'others'. Table 15 shows the raw scores obtained by the two groups (DAS and sAOS).

Table 15. Mean and SD of isolated oral movements assessing oral praxis skills.

S.No.	Oral Praxis - Isolated Oral Movements		DAS (12)	sAOS		
				ELD (6)	PD (6)	Autism (7)
1	Jaw Movement	Mean	12.33	13.66	11.50	9.71
		SD	2.64	2.06	3.01	3.09
2	Lip Movement	Mean	12.58	12.66	11.66	6.57
		SD	2.60	2.06	3.07	4.15
3	Tongue Movement	Mean	16.16	25.33	17.16	13.28
		SD	6.26	1.36	7.54	6.75
4	Others	Mean	3.58	4.33	5.00	4.42
		SD	2.57	0.51	0.89	2.63

Since the number of items in each of these categories namely, lip, jaw, tongue and others was not constant, the mean scores were converted to percentage scores in order to compare the performances between the categories within each group. Mean percentage scores were compared and are depicted in figure 8. Since percentages were compared instead of raw scores Friedman test was used to check for significant differences between the categories within each group. Wilcoxon signed rank test was then used to find out which of the categories were significantly different from one another. Table 16 shows the comparative performance of each of these movements in DAS and sAOS groups.

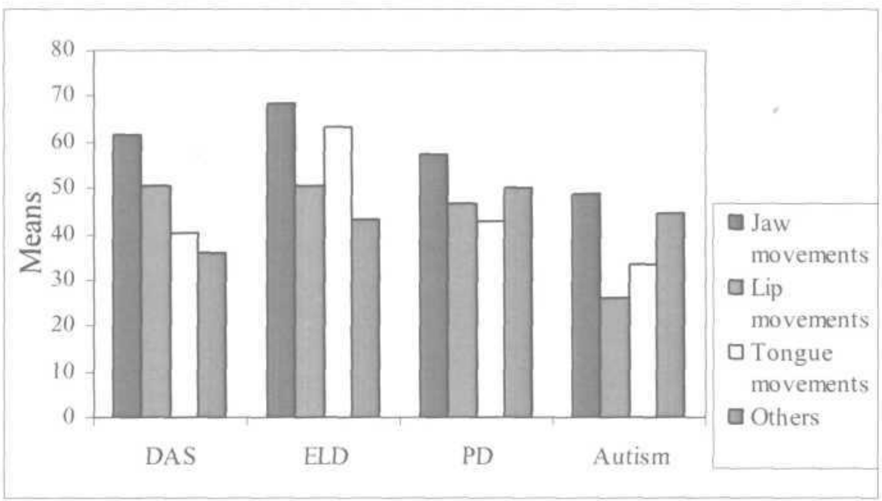

Figure 8: Percentage scores of isolated lip, jaw, tongue and other movements

Table 16: Friedman test depicting pair wise comparisons of lip, jaw, tongue and other movements within each participant group.

S.No.	Pairs of Isolated oral movements	DAS	sAOS		
			ELD	PD	Autism
		|z|	|z|	|z|	|z|
1	Jaw-lip movements	2.436**	2.271*	1.892	1.859
2	Jaw-tongue movements	2.936***	1.586	1.782	1.876
3	Jaw-other movements	2.673***	2.220*	2.060	0.508
4	Lip-tongue movements	1.883	2.220*	0.631	1.183
5	Lip-other movements	1.729	1.857	1.105	2.201*
6	Tongue-other movements	0.511	2.220*	1.054	1.524

***p<.001,**p<.01,*p<.05

From table 15, it is evident that participants with DAS exhibited poorest performance for 'other' movements followed by tongue movements. However, no significant differences were observed between others and tongue movements as is evident from table 16. The next most affected categories were the lip and jaw movements. Hence, in children with DAS, tongue, lip and 'other' movements were more affected and significantly different from jaw movements. 'Others' were more affected in DAS group due to the fact that they involved co-ordination of many different structures and systems (e.g., respiratory system involved in air build up for cough and puffing up of cheeks) unlike lip, tongue and jaw movements which involved predominant movements of the respective oral structures. Therefore, 'others' are more severely affected in DAS group followed by tongue movements, which in turn is followed by lip and jaw movements.

Within group comparisons revealed better performance i.e., better scores for lip and jaw movements compared to tongue and 'others' for participants with DAS. Amongst the sAOS groups, while ELD exhibited poor scores on 'others' similar to DAS, participants with PD and autism showed poor tongue and lip movements similar to **DAS** group. The similarity in the performance of sAOS with that of DAS group is suggestive of co-occurring oral praxis errors in ELD, PD and Autism groups. In order to depict the overlapping characteristics across DAS and sAOS, suggesting the co-occurrence of praxis deficits in sAOS groups, cluster analysis was carried out for the raw scores obtained in both isolated oral movement tasks. Cluster analysis was employed to determine the presence of clusters based on similarity in performance scores of sAOS groups with DAS group. Table 17 and figure 9 shows the number and percentage of participants clustered under clusters I, II, and III.

Table 17: Number (No.) and percentage (%) of participants clustered from **DAS and** sAOS groups for isolated oral movements

Clusters	Score range (Maximum Score: 76)	DAS		ELD		Autism		PD	
		No.	%	No.	%	No.	%	No.	%
I	13-26	3	25	0	0	3	42.85	1	16.66
II	26-39	6	50	1	16.66	3	42.85	2	33.33
III	40-50	3	25	5	83.33	1	14.28	3	50

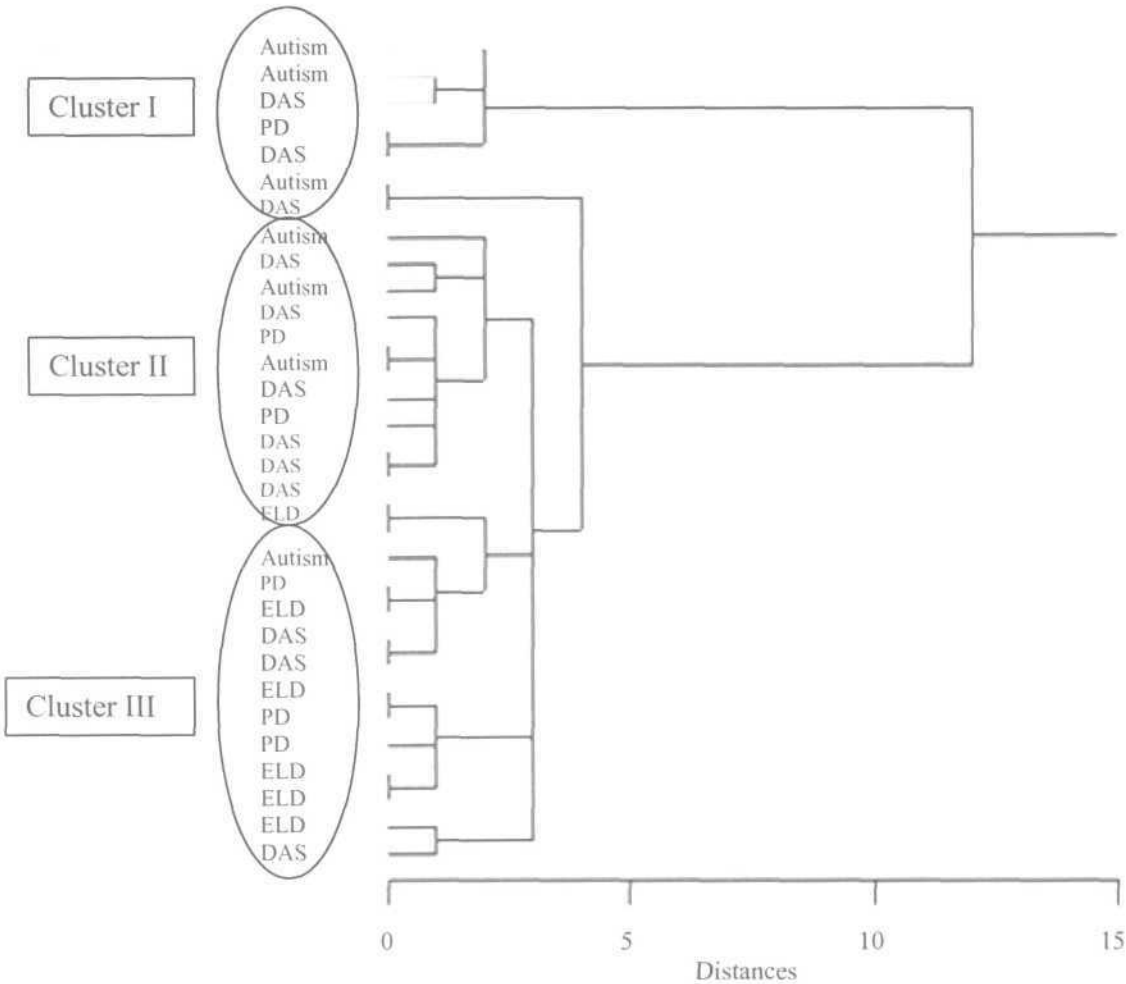

Figure 9: Cluster tree depicting the Clusters I, II and III for Isolated oral movements

Cluster I in figure 9 shows clustering of participants who exhibited greater oral praxis problems on isolated oral movements attaining the minimum score ranging from 13-26. Table 17 reveals that three (42.85%) participants with autism and one (16.66%) participant with PD performed and obtained scores similar to three (25%) participants with DAS under cluster I. None of the participants with ELD were grouped in this cluster. This shows that participants with autism and PD have performed poorly on tasks assessing oral praxis presenting severe oral praxis deficit like those with DAS in cluster I.

Cluster II shows clustering of participants who also exhibit poor performance on isolated oral praxis skills when compared to participants in cluster III. It is evident that one (16.66%) participant with ELD, three (42.85%) participants with autism, and two (33.33%) participants with PD exhibited oral praxis deficit similar to six (50%) participants with DAS.

Cluster III depicts grouping of participants who performed better than those in clusters I and II but still were not able to attain maximum score of 76 showing normal performance. It shows five (83.33%) participants with ELD, one (14.28%) participant with autism and three (50%) participants with PD, performing similar to three (25%) participants with DAS. This reveals that higher percentage of ELD children exhibited lesser errors on isolated oral movements unlike participants with PD and autism who showed oral praxis issues like those with DAS. Although the number of participants grouped under each cluster from Group I (DAS) and Group II (Suspected Apraxic Group- ELD, PD and Autism) varies, overall there is an overlap in performance scores between the participants in suspected apraxic group and developmental apraxic group, suggestive of co-occurring oral praxis deficit in sAOS groups.

In order to investigate for significant difference between the 3 clusters, 'One-way ANOVA' was employed. The mean and standard deviation (SD) for the clusters I, II and III are shown in table 18.

Table 18: Mean and Standard Deviation (SD) of three sub-groups for isolated oral movements

Clusters	N	Mean	SD
I	7	18.40	2.05
II	12	34.86	1.73
III	12	44.60	1.62

'One-way ANOVA' revealed significant difference between clusters I, II and III [f (2) = 111.560, p<0.01]. Duncan's post hoc analysis showed significant difference in performance of the participants in three clusters. Participants from sAOS and DAS in cluster I showed poor performance followed by cluster II with comparatively better scores which in turn is followed by those in cluster III with highest scores. But the results should be read with caution because participants grouped in cluster III also did not attain the maximum score (76) for normal performance on isolated oral movements tasks. Hence they also seem to exhibit oral praxis deficit.

To sum up, although the maximum score was 76, none of participants in groups with DAS and sAOS performed better on oral praxis skills. This is evident from the maximum scores attained by groups with DAS and sAOS, viz, 50 and 49 respectively. Poor oral motor imitation and other motor imitation deficits are reported as primary characteristics of childhood apraxia. As seen from tables 15 and 16, although there is no set pattern seen across the groups, it is notable that 'others' and tongue movements were maximally affected in DAS group. In sAOS groups, ELD and autism showed poor lip movements followed by tongue movements unlike PD which showed poor tongue movements as those with DAS. Poor tongue movements in both groups (DAS and sAOS) suggests difficulty in complex programming and co-ordination of oral structures. Kent (1976) reported that tongue movements are generally mastered later compared to other movements. Oral praxis deficits in terms of poor performance of non-speech movements are reported to be characteristic of children with DAS (Hall et al. 1993). Evidences for similar findings in sAOS group are reported in the literature especially pertaining to autistics. Page & Boucher (1998) suggested that oral and manual dyspraxia accounted for impaired speech and signing in children with autism. Rogers et al. (1996) reported deficits on several oral and manual praxis tasks in children with autism, with an impact on social and communicative functioning as well as speech. However no differences were reported between apraxia of speech, dysarthria, and non-motor phonological disorders. This study, thus points to presence of co-occurring deficit in oral praxis skill in sAOS groups similar to participants with DAS with supportive findings from cluster analysis.

Clustering of participants from sAOS and DAS into three different clusters is indicative of an overlap in performance scores of participants with DAS and those with ELD, PD and autism suggesting the co-occurrence of oral praxis deficit in sAOS groups. This is supported from the results of isolated oral movement assessment of oral praxis. However, there was more heterogeneity observed within the groups with DAS as well as sAOS, which is evident from the wide range of scores obtained by them. However, isolated movements alone may not be representative of oral praxis deficit as isolated movements are presumed to involve the lower levels of programming and execution in the neuro motor processes. Hence, sequential movement task was included in order to assess the performance of groups on tasks with increased complexity involving higher levels of processing.

B. Sequential oral movements

Movements in sequence were assessed and the participants were instructed to imitate the sequential movements produced by the investigator. The sequential movements were analyzed using two types of scores, namely, 'Motor control score' (MCS) and 'Sequential motor score' (SMS) (Refer Appendix 2) to calculate the appropriateness of movements and sequence respectively. Both the scores were rated on a scale of 0 to 2 to obtain the raw scores. Scores were assigned based on the responses given by the subjects as follows:

Motor control score (MCS):

'2'- Both movements are precise in every parameter

'1'- One or both movements are partially imprecise in one or more parameters

'0'- One or both movements are severely imprecise in one or more parameters

Sequence maintenance score (SMS):

'2'- Completes both movements in the order stated (correct sequence)

'1'- Completes both movements in reverse order (incorrect sequence) or adds an extra movement, or repeats a movement

'0'- Completes only one movement or completes the same movement twice

MCS rated the precision or accuracy of the two movements produced in sequence and SMS was used to rate the maintenance of sequence for each task. The maximum

MCS and SMS for this task was 10. The raw scores were statistically treated using Kruskal-Wallis test to find if there are significant differences between the experimental groups. The results of sequential oral movement tasks are depicted in Table 19 and figure 10. The Kruskal Wallis test revealed significant difference for both MCS and SMS of sequential oral movement tasks at .001 levels of significance. In order to check for the groups that significantly differed, Mann Whitney U test was carried out.

Table 19: Mean, SD and chi-square values of sequential oral movement tasks

Sequential Oral Movements		DAS (12)	sAOS ELD (6)	sAOS PD (6)	sAOS Autism (7)	Chi-square (df=3)
Motor Control Score (MCS)	Mean	4.92	6.83	8.33	5.43	14.899***
	SD	1.38	0.75	1.63	1.27	
Sequential Motor Score (SMS)	Mean	3.75	5.83	7.17	4.00	15.614***
	SD	1.60	0.75	0.98	2.58	

***p<.001

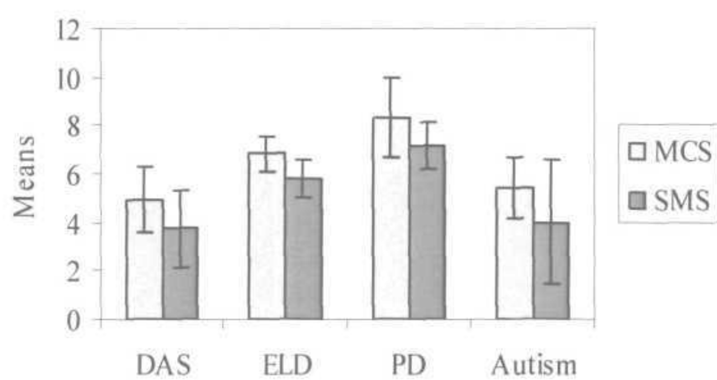

Figure 10: Means and SDs for sequential oral movements

Participants with DAS exhibited significantly greater oral praxis problems in sequential movements than participants belonging to ELD and PD groups with sAOS in terms of accuracy (MCS). Autism group obtained similar MCS like participants with DAS and they did not differ significantly from each other in terms of accuracy. For participants with DAS, the MCS and SMS scores ranged from 3 to 7 and 0 to 5, respectively. On the other hand, amongst the sAOS groups, participants with autism exhibited greater errors followed by ELD and PD groups. MCS scores for participants with ELD, PD and autism ranged from 6 to 8, 6 to 10 and 4 to 7 respectively. For SMS, the scores ranged from 5 to 7, 6 to 8 and 0 to 8 for ELD, PD and autism, respectively. The findings reveal that children with DAS and sAOS produce imprecise movements and also have difficulty maintaining the sequence. It is notable that DAS group scored very poor on accuracy of movements (MCS) as well as sequential motor score (SMS) than sAOS group. The sequencing difficulties are reported as hallmark characteristics of DAS and the finding of this study supports the previous findings in literature.

Children with autism have shown maximum imprecision with least MCS followed by those with ELD. PD group exhibited lesser errors with significantly better scores on sequential oral movement tasks. Both DAS and sAOS have followed similar patterns with better scores on MCS which measures accuracy of movements and least scores on SMS which measures the sequence maintenance ability. Overall, maintenance of sequence was more affected in both the groups (DAS and sAOS) although movements were relatively more precise. Presence of sequential difficulty in sAOS groups points to the presence of oral praxis deficit in these children (ELD, PD and Autism) similar to that of DAS group.

In PD group also, precision of movements was better which is evident from the higher scores on MCS when compared to sequence maintenance ability with lower scores on SMS. Among the sequential tasks of bite & blow, blow & smile, smile & kiss, bite and open mouth, kiss & stick tongue out, both groups of participants showed extremely poor performance in terms of accuracy and maintaining sequence on blow and smile, smile and kiss, bite and blow and kiss and stick tongue out. Both groups performed better on bite and open mouth probably because of the involvement of same oral structure that is jaw. In other double oro-motor sequences, although the articulator involved was same in two tasks that is lips, they required faster and smooth transition which was difficult for participants in both the groups. Participants with DAS and sAOS required more number of repetitions to perform the movements. As sequencing deficit is characteristic of developmental apraxia of speech, poor sequencing ability in sAOS groups is suggestive of co-occurring oral praxis deficit in groups with ELD, PD and autism similar to group with DAS.

In order to depict the co-occurrence of praxis deficits in sAOS groups and presence of overlapping characteristics across groups with DAS and sAOS, cluster analysis was carried out. Since sequencing difficulties characterizes apraxia of speech in children, the experimental groups were analyzed based on sequential motor scores. Sequential motor scores were subjected to cluster analysis to determine the presence of clusters based on the performance scores of participants with DAS and sAOS. Table 20 and Figure 11 shows the number and percentage of participants clustered under clusters I, II, and III.

Table 20: Number (No.) and percentage (%) of participants clustered from DAS and sAOS groups for Sequential Oral Movement tasks.

Clusters	Score range (Maximum Score: 10)	DAS		ELD		Autism		PD	
		No.	%	No.	%	No.	%	No.	%
I	0-3	9	75	0	0	2	28.57	0	0
II	4-5	3	25	2	33.33	4	57.74	3	50
III	6-8	0	0	4	66.66	1	14.28	3	50

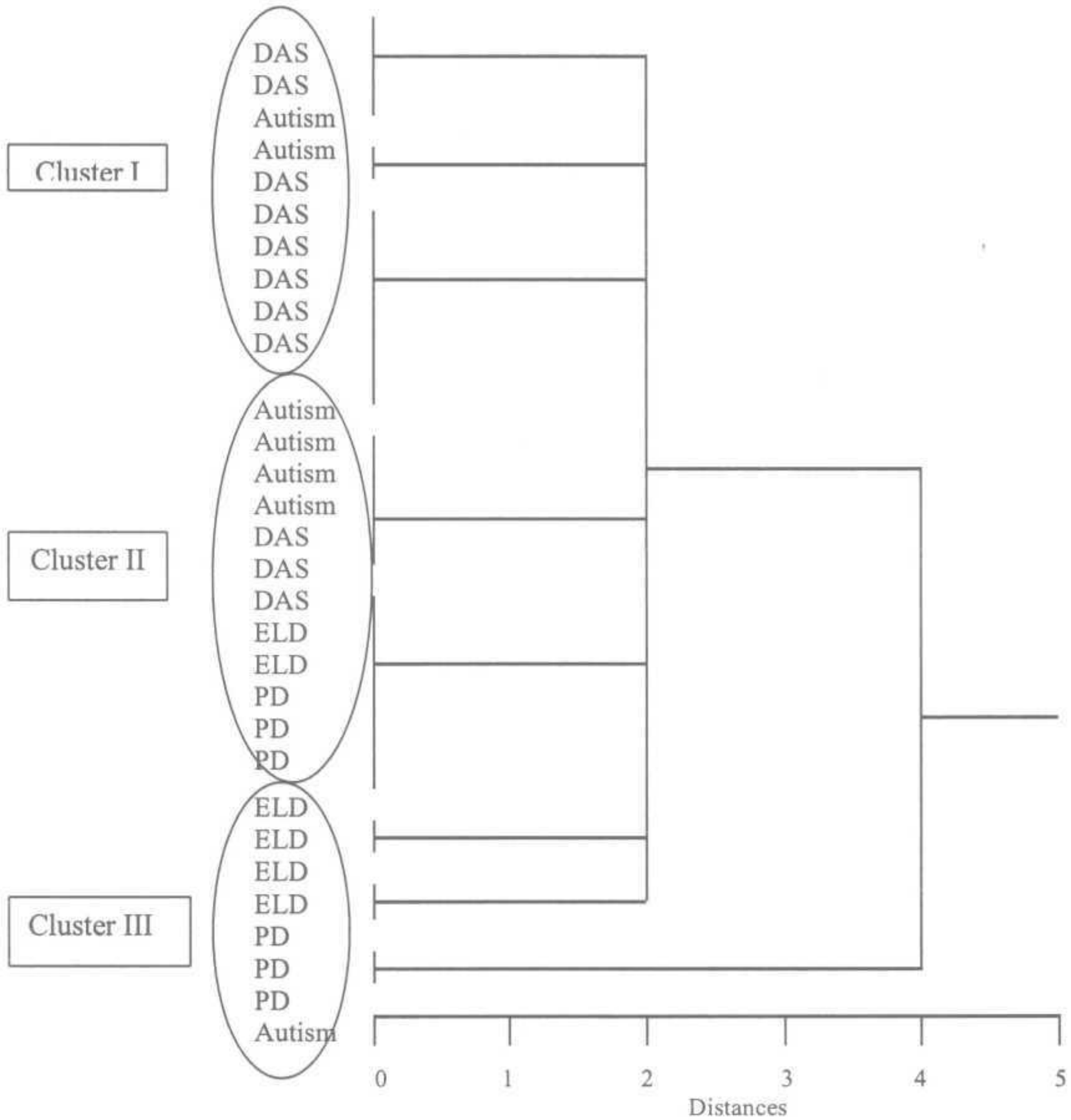

Figure 11: Cluster tree depicting the Clusters I, II and III for Sequential Oral Movement tasks

The maximum score for this parameter is 10. Cluster I in Table 20 shows clustering of participants exhibiting greater errors on sequential oral praxis skills attaining the lowest score ranging from 0-3. It reveals that two (28.57%) participants with autism performed similar to nine (75%) participants with DAS in cluster I. None of the participants with ELD and PD were grouped under this cluster. This shows that participants with DAS and autism have performed poorly on sequential oral movement tasks assessing oral praxis skills and hence exhibit severe sequential oral praxis deficit.

Cluster II shows clustering of participants who exhibited moderate difficulty with scores ranging from 4 to 5, in performing the sequential tasks thus showing a poor performance compared to participants in cluster III. It is notable that two (33.33%) participants with ELD, four (57.74%) participants with autism and three (50%) participants with PD exhibit poor sequencing ability similar to three (25%) participants with DAS on tasks assessing sequential oral movements.

Cluster III shows clustering of participants who performed better with lesser sequencing errors than participants in clusters I and II but still were not able to attain the maximum score of 10, showing normal performance. Four (66.66) participants with ELD, one (14.28%) participant with autism and three (50%) participants with PD clustered under this group with relatively better performance. However they also exhibited sequencing difficulty, which is evident from the poor scores. None of the participants with DAS were grouped in this cluster. This shows that higher percentage of ELD children performed better with relatively lesser errors on sequential tasks assessing oral praxis where as participants with PD and autism show severe deficits similar to DAS.

Amongst those with sAOS, children with autism performed more similar to DAS. Although the percentage of participants grouped in each cluster varied, the results shows that there is an overlap of sequencing deficit in participants with suspected apraxia of speech similar to participants with DAS, pointing to the co-occurrence of sequential oral praxis deficit in sAOS groups.

In order to verify for significant difference between the performances of participants in 3 clusters, 'One-way ANOVA' was employed. The mean and standard deviation (SD) for the clusters I, II and III are shown in Table 21.

Table 21: Mean and Standard Deviation (SD) of three clusters for Sequential Oral movement tasks

Clusters	N	Mean	SD
I	11	0.55	0.52
II	12	2.00	0.00
III	8	3.13	0.35

'One-way ANOVA' revealed significant difference between clusters I, II and III [f (2) = 123.655, p<0.01]. Duncan's post hoc analysis revealed significant difference in the performance of participants grouped in three clusters with cluster I showing a poorer performance followed by cluster II with comparatively better scores which in turn was followed by cluster III with highest scores on sequential tasks. But the results should be interpreted cautiously because participants in cluster III did not attain the maximum score indicative of normal performance. Hence participants with sAOS seemed to present co-occurring sequential oral praxis deficit like the DAS group

Many investigators have suggested the existence of a group of children who have severe difficulty producing speech and whose disorder appears to have components of 'dyspraxia', that is difficulty in planning and sequencing articulatory movements. These children are said to have more than just a phonological disorder (Crary, 1993; Velleman & Strand, 1994; Whitebread, Dvorak, & Jakielski, 1999; Velleman, 2002). Sequencing difficulty is said to result in motor struggle (Velleman, 2002). Crary and Anderson (1991) consider DAS as a disorder of motor sequencing. In a study by Dewey and Kaplan (1992), investigating children with motor deficits for academic and language abilities, two of the four groups presented difficulty with praxis (voluntary movement) and sequencing tasks, suggesting a close relationship between praxis deficits and language-based skills. The problem seems to exist between the transitions of movements. The more complex the transitions, the more difficulty the child is likely to have. Frequently, children who are diagnosed with DAS may have both a mild motor control and a sequencing problem (Hayden, 2002).

In addition, it is reported that increase in complexity of tasks results in increased errors in children with praxis deficits. Since sequential tasks are more complex and requires precise motor control compared to isolated tasks, they are more sensitive in identifying praxis deficits (Velleman, 2003). As seen from the results of oral praxis section, it is evident that sequential tasks serve as effective indicators to identify praxis deficit in the sAOS group. Oral praxis deficit were more evident in participants with sAOS when assessed using sequential tasks although the severity of oral praxis deficit is evidently more for the DAS group.

The results from oral praxis assessment section revealed that individuals with sAOS groups exhibited oral praxis problems similar to participants with DAS. While most of the participants with ELD, PD and autism (sAOS groups) exhibited deficits in oral praxis deficits, variability existed as evident from varying percentages of individuals in the three clusters. Apart from the variability, it was also difficult to determine whether the oral praxis skills are affected due to oral motor problems or solely due to oral praxis deficits. This was answered in part with the help of sequential oral praxis assessment, which involved sequences of double oro-motor movements. Accuracy and sequence of oral movements were affected in groups with sAOS similar to that seen in participants with DAS. Also, autism and PD groups with sAOS exhibited similar oral praxis errors like the DAS group for isolated oral movements when compared to participants with ELD. On the other hand, participants with ELD and autism exhibited similar sequencing errors like those with DAS on sequential tasks. PD group exhibited sequencing errors but relatively lesser than other groups. Thus, it is evident that sAOS groups revealed varying degree of co-occurring oral praxis deficits similar to praxis deficits evidenced in participants with DAS. Apart from oral praxis skills, verbal praxis skills were also assessed for participants in both the groups to explore for the presence of verbal praxis deficits in these groups and the results are discussed in further sections.

3) Verbal praxis skills

Verbal praxis deficits such as errors in sequencing articulatory movements have been reported to occur frequently in children with DAS (Hall, Jordan & Robin, 1993;

Crary, 1993; Velleman, 2003). Verbal praxis skills assessment included tasks that increased in complexity from simple to complex levels, ranging from isolated speech movements to spontaneous speech. The stimuli used for assessment of isolated and sequential verbal movements were not language specific. The other sections were assessed using words and sentences that were prepared specifically in Kannada. Spontaneous speech was also assessed in Kannada. Following are the various tasks that were included in this section:

A. Isolated verbal movements
B. Sequential verbal movements
C. Word level praxis assessment
D. Sentence level praxis assessment
E. Analysis of spontaneous speech

A) Isolated verbal movements

Vowels, continuant consonants such as /ʃ../, /m../, /n../, /l../ and CV syllables with unaspirated consonants (occurring in initial position in Kannada) and schwa vowel were included as stimuli to assess isolated verbal movements. Participants were instructed to imitate speech sounds uttered by the investigator. The responses of the participants were rated based on the accuracy and number of repetitions required to elicit the response. A maximum of two repetitions were given if the participant did not imitate the sounds properly and was then rated accordingly on a 3-point rating scale (Refer Appendix II):

'3'- Movement/action is accurate

'2'- Movement/action is accurate with one repetition

'1'- Movement/action is inappropriate with more than one repetition

'0' - Child is unable to perform even with repetitions

A total of twenty-two tasks divided on the basis of predominant use of jaw, lip and tongue movements were incorporated in this section. All the responses were transcribed and raw scores were subjected to statistical analysis using one-way ANOVA in order to compare the performance across the two groups. Table 22 and Figure 12 depicts the mean and SD for isolated verbal movements. From results in Table 22, it is seen that one-way ANOVA did not reveal any significant difference between the two groups (DAS and sAOS). For a maximum score of 66, the range of scores obtained by participants with DAS (23 to 50) and sAOS were between 31 to 47 for ELD, 20 to 49 for PD and 25 to 51 for autism. The range of scores was almost similar across the groups with sAOS.

Table 22: Mean, SD and one-way ANOVA for isolated verbal movements.

Verbal Praxis assessment (Maximum Score: 66)	DAS (N:12)		sAOS						
			ELD (N:6)		PD (N:6)		Autism (N:7)		
	Mean	S.D	Mean	S.D	Mean	S.D.	Mean	S.D.	F (3,27)=F
Isolated verbal movements	36.06	6.32	38.39	5.94	37.43	9.24	39.99	9.79	0.224

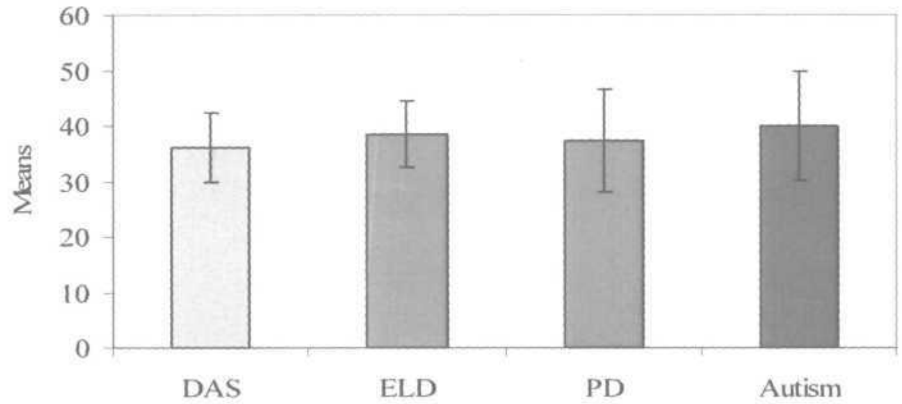

Figure 12: Mean and SD for isolated verbal movements

As seen from the mean scores in table 22 and figure 12, the findings shows that participants with DAS obtained poorer scores when compared to sAOS groups but were not significantly different. In sAOS groups, PD showed poor scores when compared to those with ELD and autism but did not differ significantly from one another. It is notable that children with sAOS showed similar verbal praxis scores as that of DAS. Although participants with DAS and sAOS performed poorly on isolated verbal movements, there was evident heterogeneity within the groups as revealed from the SD values. This shows that not all the participants in groups with DAS and sAOS exhibited same degree of severity in verbal praxis of isolated verbal movements. Moreover, not all the tasks were equally affected in individuals with sAOS and DAS. The mean raw scores and SDs of isolated verbal movements for lip, jaw and tongue structures are depicted in table 23. Since the number of items in each of these categories namely, lip, jaw, and tongue movements were not constant, the mean scores were converted to percentage scores in order to compare the performances between the categories of each group. Mean percentage scores for individual structures are depicted in figure 13.

Table 23: Mean and SD for isolated verbal movements of lip, tongue and jaw.

S.No.	Verbal Praxis - Isolated Verbal Movements		DAS (12)	sAOS		
				ELD (6)	PD (6)	Autism (7)
1	Jaw Movement	Mean	9.88	10.75	9.63	9.75
		SD	1.23	0.61	2.66	1.84
2	Lip Movement	Mean	9.75	9.38	8.50	8.89
		SD	1.11	0.92	1.62	1.26
3	Tongue Movement	Mean	16.43	18.26	19.30	20.68
		SD	5.08	3.31	5.94	6.75

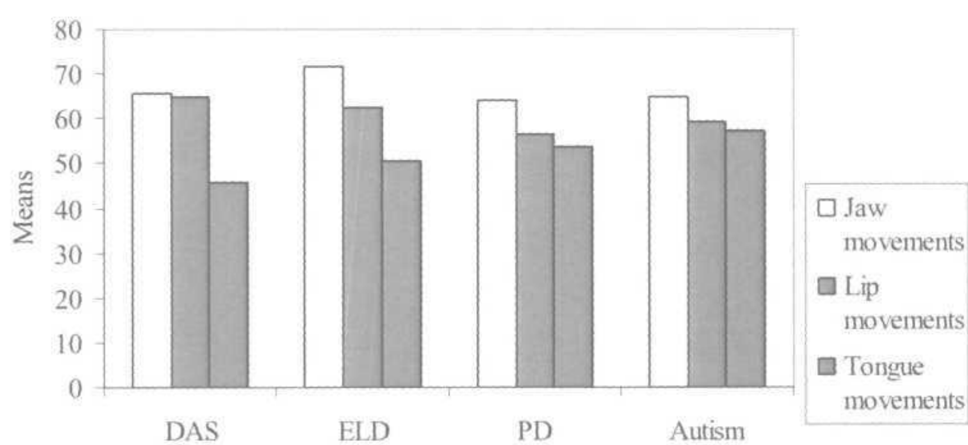

Figure 13: Percentage scores for isolated jaw, lip and tongue movements

Table 23 and figure 13 reveals that groups with DAS and sAOS achieved similar scores exhibiting similar verbal praxis errors on isolated verbal movements. Both groups achieved higher scores for isolated verbal movements of jaw, followed by lips and lowest scores for verbal movements involving the tongue. Friedman test was carried out to find if there is any significant difference with in each of these groups for the individual movements involved. Wilcoxon signed rank test was then used to find out which of the categories were significantly different from one another. Table 24 shows the results of Friedman test.

Table 24: Friedman-test comparing lip, jaw, and tongue movements within DAS and sAOS groups

Pairs of Isolated oral movements	DAS	sAOS		
		ELD	PD	Autism
	$\|z\|$	$\|z\|$	$\|z\|$	$\|z\|$
Lip-Jaw movements	0.259	2.232*	2.201*	2.366**
tongue-Jaw movements	3.059***	2.207*	2.201*	2.366**
tongue-Lip movements	3.061***	2.232*	2.201*	1.521

***p<.001,**p<.01,*p<.05

A similar trend in terms of the movements affected was observed in groups with DAS and sAOS. From Table 24, it is evident that speech sounds that involved tongue movements were affected the most and speech sounds involving jaw movements were least affected followed by lip movements in children with DAS. Wilcoxon signed rank test showed that significant differences were present between jaw-tongue movements and tongue-lip movements but not between lip and jaw movements. In children with sAOS also, similar pattern of errors were observed with in each group (ELD, PD and autism). In ELD, speech sounds involving tongue movements were significantly different from lip and jaw movements.

PD and autism also showed similar findings with more errors on speech sounds involving tongue movements compared to those involving movements of lip and jaw. This could be attributed to the fact that speech sounds involving tongue movements are more difficult and are generally acquired later. For example, the retroflex stops involving tongue movements are generally acquired later (Shyamala & Basanti, 2003) and fricatives, considered as more difficult sounds also require greater precision of articulators for their production. Moreover, since continuant sounds like, *l\l, III,* /m/ were included as stimuli, it would have perhaps posed more difficulty in producing them continuously. As Kannada is a language incorporating words with vowel endings, the children probably had more difficulty in producing only the consonants in the form of continuants. Also, sounds such as retroflex involving complex transition of tongue movements were difficult for children in both groups, viz., DAS and sAOS. Thus tongue movements were maximally affected in sAOS groups similar to DAS group indicating co-occurrence of verbal praxis deficit in sAOS.

To verify the co-occurrence of verbal praxis deficits in sAOS groups, the raw scores were subjected to cluster analysis that generated three clusters. The clusters represent grouping of sAOS participants, who have performed and obtained scores similar to participants with DAS. Table 25 shows the number and percentage of participants clustered under clusters I, II, and III. Figure 14 shows the clusters obtained isolated verbal movement tasks.

Table 25: Number (No.) and percentage (%) of participants clustered from groups with DAS and sAOS for Isolated Verbal Movements

Clusters	Score range (Maximum Score: 66)	DAS		ELD		Autism		PD	
		No.	%	No.	%	No.	%	No.	%
I	20-29	3	25.00	0	0	2	28.57	1	16.66
II	31-39	7	58.33	4	66.66	1	14.28	3	50.00
III	41-51	2	16.66	2	33.33	4	57.74	2	33.33

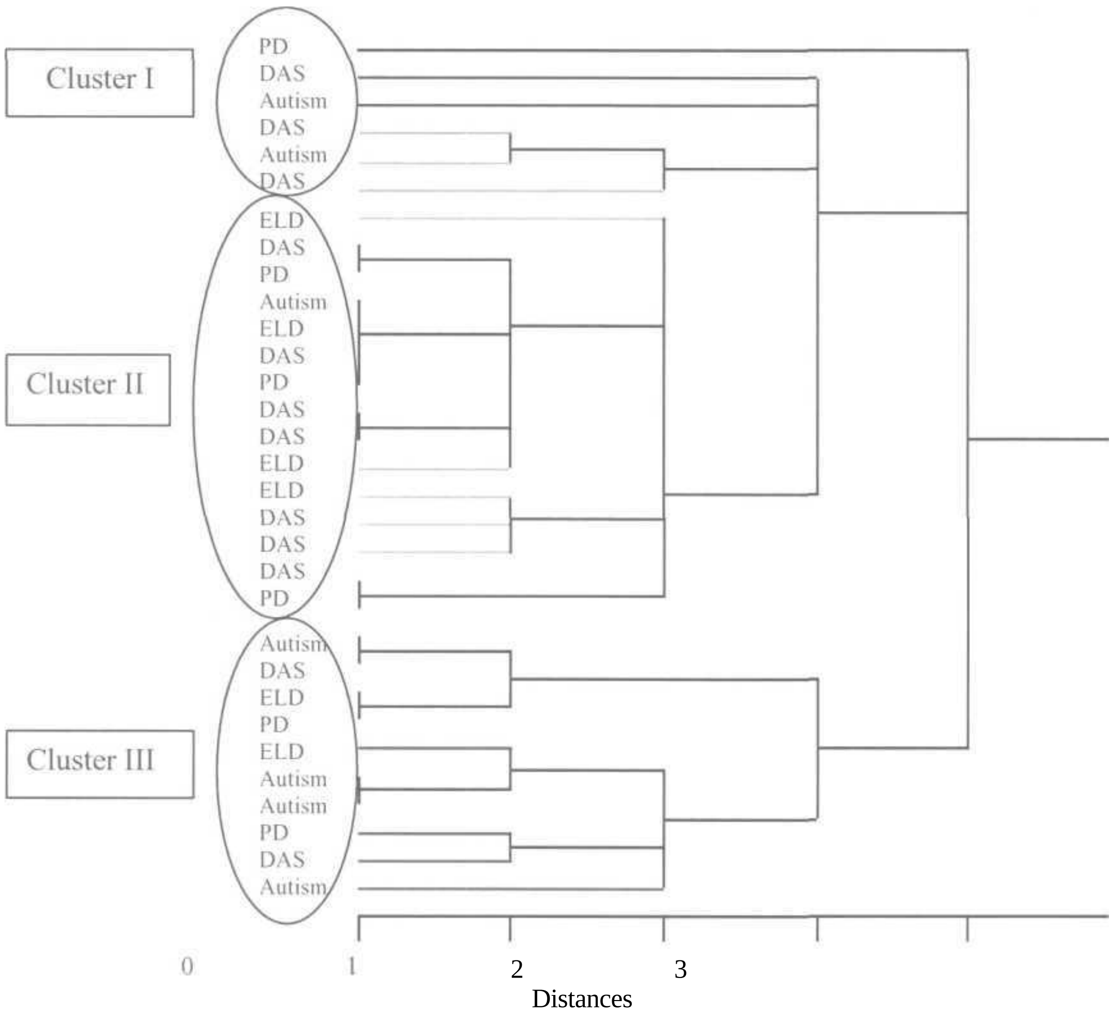

Figure 14. Cluster tree depicting the Clusters I, II and III for isolated verbal movements.

Cluster I in table 25 shows clustering of participants with poorest performance on verbal praxis attaining the lowest score ranging from 20-29. It is evident that two

(28.57%) participants with autism and one (16.66%) participant with PD exhibited verbal praxis deficits similar to three (25%) participants with DAS in cluster I. This reveals that participants from sAOS groups (PD and autism) showed greater errors on tasks assessing isolated verbal movements thereby exhibiting severe verbal praxis deficit similar to DAS group. None of the participants with ELD were grouped under this range of scores.

Cluster II shows clustering of participants who had moderate difficulty in performing isolated verbal movements consequently showing a poor performance on verbal praxis skills compared to cluster III. It is notable that four (66.66%) participants with ELD, one (14.28%) participant with autism and three (50%) participants with PD showed poor scores ranging from 31-39 similar to seven (58.33%) participants with DAS on isolated verbal movements.

Cluster III depicts grouping of participants who performed better but with relatively lesser errors on isolated verbal movements when compared to participants grouped in clusters I and II. It shows two (33.33%) participants with ELD, four (57.74%) participants with autism and two (33.33%) participants with PD, exhibiting similar verbal praxis errors like two (16.66%) participants with DAS. While four of seven autistic children perform better on isolated verbal praxis movements, majority of the participants with PD and ELD show severe deficits just like those with DAS. Although the number of participants under each cluster grouped from Groups I (DAS) and II (Suspected Apraxic Group-ELD, PD and Autism) varied, the results shows that there is an overlap in the scores obtained by participants in suspected apraxic group and developmentally apraxic participants indicating the co-occurrence of verbal praxis deficit in sAOS groups.

In order to check for significant difference between participants grouped under the 3 clusters, 'One-way ANOVA' was employed. The mean and standard deviation (SD) for the clusters I, II and HI are shown in table 26.

Table 26: Mean and Standard Deviation (SD) of three clusters for isolated verbal movements

Clusters	N	Mean	SD
I	6	25.12	2.85
II	15	35.25	1.40
III	10	45.82	2.54

The results of 'one-way ANOVA' revealed significant difference between clusters I, II and III [f (2) = 105.802, p<0.01]. Cluster I exhibited greater verbal praxis errors followed by cluster II with comparatively better scores which in turn is followed by cluster III with highest scores. But again the results should be cautiously interpreted because participants with DAS and sAOS in cluster III also did not attain the maximum score of 66, showing normal performance. Hence sAOS participants in cluster III also showed signs of verbal praxis deficit same as the DAS group.

Thus, the results on verbal praxis assessment for tasks involving isolated verbal movements revealed that participants with sAOS exhibited greater verbal praxis deficits similar to participants with DAS. Moreover the sAOS groups showed a similar trend in terms of sounds affected with respect to articulatory movements. In other words, sounds involving tongue movements were affected the most in sAOS groups followed by movements of lips and jaw. Similar trend was observed in children with DAS. Although, the isolated verbal tasks may be indicative of co-occurrence of verbal praxis deficits in the sAOS group who obtained similar scores as the DAS group, the findings need to be looked into with supportive data on tasks involving more complex sequential verbal movements, In order to rule out the effect of oral motor issues, tasks involving sequences of verbal movements may serve as better indicators of verbal praxis deficits in sAOS groups.

B. Sequential verbal Movements

In this section, tasks with two- and three- sound combinations including vowels and consonant continuants in Kannada were used as stimuli. The participants were instructed to imitate the verbal model provided by the investigator. Similar to the scoring carried out for sequential oral movements, the responses were evaluated in terms of Motor control score (MCS) to rate the accuracy of speech movements and sequential motor score (SMS) to rate the maintenance of sequence of the target speech movements. A rating scale ranging from 0 to 2 ('0' depicting poor scores) was used to rate the responses (Refer Appendix II).

For a total score of 14, raw scores of participants with DAS for MCS ranged from 4 to 10 and for SMS, the raw scores ranged from 3 to 7. On the other hand, raw scores of individuals with ELD ranged from 10 to 12 for MCS and 7 to 10 for SMS. Raw scores of

PD group ranged from 8 to 11 for MCS and 5 to 8 for SMS. For participants with autism, MCS ranged from 6 to 11 and SMS ranged from 3 to 8. Table 27 and figure 15 shows the group means and SDs for sequential verbal movements. The raw scores were subjected to Kruskal Wallis test to check for significant differences between the groups. Mann Whitney U test was carried out to explore the individual groups that differed significantly.

Table 27: Mean and SD of individual movements in sequential verbal movement tasks

Sequential verbal Movements			sAOS			
		DAS (12)	ELD (6)	PD (6)	Autism (7)	Chi-square (df=3)
Motor Control Score (MCS)	Mean	7.00	10.85	10.03	8.30	17.161***
	SD	1.86	0.73	0.96	1.83	
Sequential Motor Score (SMS)	Mean	4.83	8.67	7.00	5.86	15.540***
	SD	1.03	1.21	1.26	2.12	

*** p< .001

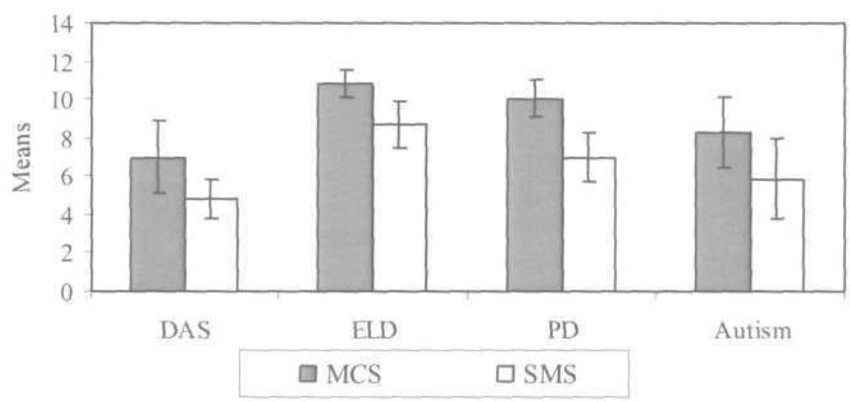

Figure 15: Means and SDs for sequential verbal movements

Results in table 27 and figure 15 revealed significant differences across the two groups with DAS and sAOS, for both MCS and SMS of sequential oral movement tasks at .001 levels of significance. Mann Whitney U test revealed that individuals with DAS significantly differed from groups with PD and ELD for MCS and SMS. DAS showed poor accuracy and sequencing (as revealed by MCS and SMS) of two- and three- sound movements on all the sequential verbal tasks. In sAOS group, autistics did not differ significantly from DAS indicating similar sequential deficits as DAS with least MCS and SMS when compared to ELD and PD. Although the ELD and PD groups showed poor performance with inaccurate production of speech sounds and inadequate maintenance of sound sequences, they exhibited significantly less verbal praxis errors compared to groups with autism and DAS. Among the two- and three- speech sound combinations, both groups with DAS and sAOS obtained very poor scores on sequences that involved the continuant consonant /m/ (e.g. a-m-u) compared to combinations that had only vowels (e.g. a-u / o-i). sAOS groups showed poor accuracy in the production of 'a-m-u' and "m-o-i' when compared to other sound combinations. This could be because of the fact that kannada language is syllable timed constituting words with vowel endings. Hence they produced the continuant An/ as a syllable /ma/.

The findings for sequential verbal movement tasks in children with DAS and sAOS is similar to that observed for sequential oral movements. Both DAS and sAOS have followed similar patterns with better scores on MCS measuring accuracy of movements and least scores on SMS indicating poor sequence maintenance. Sequencing was more affected in all the groups although movements were relatively precise. Greater sequential difficulty in sAOS group is in favor of the presence of praxis deficit in these children similar to that observed for DAS group.

Since MCS rated the accuracy of speech sound production, only SMS was subjected to cluster analysis to determine the existence of clusters based on a comparison of performance scores of groups with sAOS and DAS. Table 28 shows the number of participants clustered under clusters I, II, and III. Figure 16 depicts the clusters obtained on sequential tasks assessing verbal praxis skills.

Table 28: Number of participants clustered from DAS and sAOS groups for sequential verbal tasks

Clusters	Score range (Maximum Score: 10)	DAS		ELD		Autism		PD	
		No.	%	No.	%	No.	%	No.	%
I	3-4	8	66.66	0	0	3	42.85	0	0
II	5-7	4	33.33	2	33.33	2	28.57	2	33.33
III	8-10	0	0	4	66.66	2	28.57	4	66.66

The maximum score for this parameter was 14. Cluster I in Table 28 shows clustering of participants exhibiting greater errors on sequential verbal praxis tasks attaining the minimum score ranging from 3-4. It is found that three (42.85%) participants with autism had greater sequencing deficits similar to eight (66.66%) participants with DAS, clustered under cluster I. This shows that these participants from sAOS have performed poorly on sequential verbal tasks assessing verbal praxis skill thus exhibiting severe verbal praxis deficit similar to that of DAS group. None of the participants with ELD and PD were grouped under this cluster.

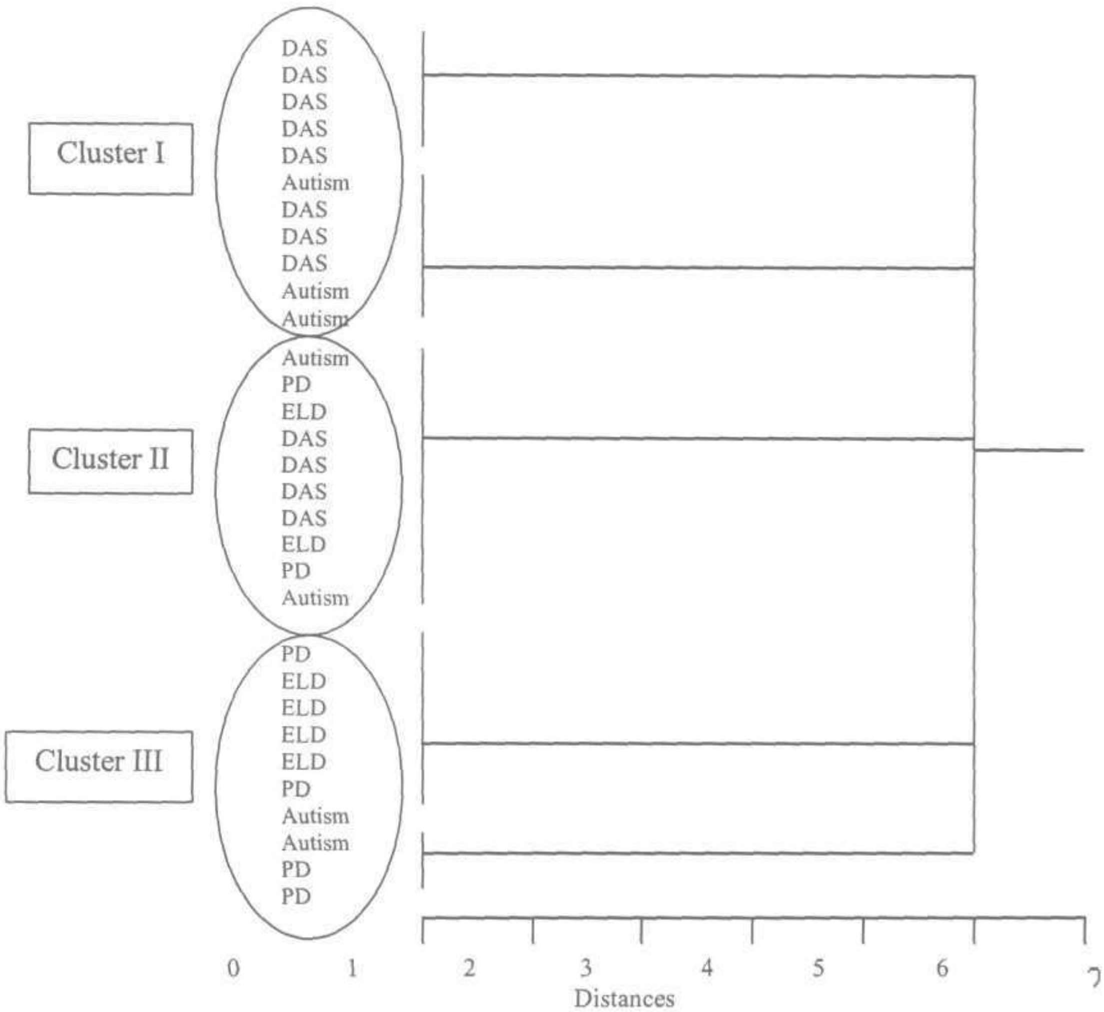

Figure 16. Cluster tree depicting the Clusters I, II and III for sequential verbal tasks

Cluster II shows clustering of participants exhibiting sequencing difficulty on sequential verbal praxis movements with moderate severity when compared to participants grouped in cluster III. It is evident that two (33.33%) participants with ELD, two (28.57%) participants with autism and two (33.33%) participants with PD showed sequential verbal praxis deficit similar to four (33.33%) participants with DAS, in performing tasks assessing sequential verbal praxis skills.

Participants in cluster III attained a maximum score of 10 for a total score of 14, thus showing grouping of participants who had relatively lesser or mild sequencing difficulty than participants in clusters I and II. It shows four (66.66%) participants with ELD, two (28.57%) participants with autism and four (66.66%) participants with PD with similar scores. This shows that higher percentage of participants with ELD and PD perform better on sequential tasks assessing verbal praxis skills where as participants with DAS and autism show severe sequential deficits. Although the number of participants in each cluster from groups with DAS and sAOS were not uniform, the results show that there is an overlap in terms of sequencing deficits between the participants in suspected apraxic group like in developmental apraxic participants indicative of verbal praxis deficit in sAOS group.

In order to check for significant difference between the 3 clusters, 'One-way ANOVA' was employed. The mean and standard deviation (SD) for the clusters I, II and III are shown in the following table.

Table 29: Mean and Standard Deviation (SD) of three clusters for sequential verbal movements.

Clusters	N	Mean	SD
I	11	0.55	0.52
II	10	2.00	0.00
III	10	3.30	0.48

Group comparison using 'One-way ANOVA' revealed significant difference between the clusters I, II and III [f (2) = 115.666, p<0.01]. Duncan's post hoc analysis revealed significant difference in the performance of the three sub-groups with sub-group I showing a poorer performance followed by cluster II with fairly better scores which in turn is followed by cluster III with highest scores. However, participants under cluster III also did not attain the maximum score of 72. Hence they also seem to present with sequential verbal praxis deficit.

To summarize the results as evident from sequential verbal movement tasks, it is seen that participants with DAS performed significantly poorer with more number of errors both in terms of accuracy (MCS) and sequencing (SMS). Participants with autism also showed similar errors with poor sequencing and accuracy on sequential verbal tasks compared to those with PD and ELD, indicating the presence of verbal praxis deficit. Participants with ELD and PD exhibited errors in terms of accuracy and sequencing although scores were better compared to other groups yet signifying the presence of verbal praxis deficit. This finding could serve as an indicator of praxis deficit because of the less variability evident with in these groups on sequential verbal movements. In addition, both groups of participants (DAS and sAOS) had difficulties in movements involving continuant consonants. Sequencing errors are typical indicators of praxis breakdown at a higher level in DAS. Since both groups with DAS and sAOS obtained poor sequential motor scores when compared to motor control score for precision of verbal movements, they could be interpreted as due to verbal praxis deficits rather than issues like mild tone deficits and motor execution issues. Since these deficits are observed in sAOS groups, it reveals the co-occurrence of verbal praxis deficits in groups with ELD, PD and autism.

Another characteristic error for praxis deficit in DAS is reported as increase in errors with increasing complexity (Robin, 1992; Hall, Jordan & Robin, 1993; Thoonen et al., 1997). In further sections, performances of the groups are reported for tasks using words of increasing complexity and sentences.

C) Word level praxis assessment

The word level task included a list of forty words from Kannada language. The list comprised five words each from bisyllabic, trisyllabic and multisyllabic words with and without clusters, that is, geminated and non-geminated words. The whole list of words was finalized after consulting a linguist who examined the word list for dialectal appropriateness of words. All words were arranged in a hierarchy of increasing length and presence of clusters as follows:

- Disyllabic words without clusters
- Disyllabic words with clusters
- Trisyllabic words without clusters
- Trisyllabic words with clusters
- Multisyllabic words without clusters
- Multisyllabic words with clusters
- Disyllabic words with two clusters-one in the initial and one in the medial position
- Multisyllabic words with two clusters-one in the initial and one in the medial position.

The participants were instructed to repeat the words after the investigator. The responses were recorded and transcribed verbatim using Broad International Phonetic Alphabet (IPA) system of transcription. The transcribed utterances were analyzed for following phonological errors:

1. Phonological process assessment
    a) Types of phonological processes
    b) Percentage occurrence of the phonological processes
    c) Percentage of persons exhibiting various phonological processes
2. Groping, dysfluencies and weak precision
3. Syllable sequence measured using sequence maintenance score

1) Phonological process assessment

Phonological processes are the descriptive terms used to identify patterned misarticulations in children's speech. This type of analysis is often recommended for use with highly unintelligible children who have multiple misarticulations (Velleman, 1998; Hegde & Penabrooks, 2000; Bleile, 2004) and those having idiosyncratic processes (Stoel-Gammon & Dunn, 1985; Grunwell, 1997; Bankson & Bernthal, 1998). Traditionally the phonological processes are categorized as a) syllable structure processes, b) substitution processes, and c) assimilation processes (Stoel-Gammon & Dunn, 1985; Bernthal & Bankson, 1998). There are some processes which occur infrequently in children with normal phonological skills and these are termed as unusual or idiosyncratic processes (Stoel-Gammon & Dunn, 1985; Grunwell, 1997; Bernthal & Bankson, 1998). In addition to the traditional approach to classification, Velleman (2003) categorized phonological processes as space errors / accuracy errors, timing errors and whole word errors (sequencing or whole-word planning). These patterns are identified based on the underlying type of error observed in the process. In this study, speech samples of the participants in group I (DAS) and II (sAOS) were categorized into space, timing and whole word errors (Velleman, 2003).

Phonological processes can also be assessed according to their frequency and percentage of occurrence. In frequency of occurrence, the number of times a particular process occurs in the individual's speech sample is calculated. Percentage of occurrence is reported to be more specific, wherein the clinician determines the number of times the child uses a particular phonological process in relation to the total number of opportunities that were present to use that process. The significance of information is said to be enhanced if the percentage of occurrence is known. To calculate the percentage of occurrence of a process, the clinician needs to determine the total number of opportunities for the use of a specific phonological process in addition to the total number of actual occurrences (Pena-Brooks & Hegde, 2000).

In this study, various phonological processes were analyzed from the transcribed utterances for: (a) various types of processes classified into space, timing, and whole word errors, (b) percentage occurrence of each phonological process and (c) percentage of persons exhibiting various phonological processes.

a) Types of phonological processes:

The different phonological processes identified from transcribed utterances were categorized into space errors, timing errors and whole word errors. This categorization

r

was done to facilitate assessment for praxis deficit in the suspected apraxic group (sAOS). This error categorization is recommended by Velleman (2003) for phonological errors seen in children with DAS. Phonological processes were analyzed based on the definitions of phonological processes described by Stoel-Gammon, and Dunn (1985), Velleman (1998) and Pena-brooks & Hegde (2000). Other phonological processes that are not traditionally described in literature but are relevant in Kannada language such as gemination, degemination etc were also included in the analyses. The processes that were categorized under these error patterns are listed below:

- *Space errors:* fronting, backing, palatalization, depalatalization, and vowel deviations including vowel prolongation, vowel centralization, monophthongization.
- *Timing errors:* affrication, deaffrication, denasalization of nasal continuants, prevocalic voicing, postvocalic devoicing.
- *Whole word errors:* sequencing errors like reduplication, consonant harmony, migration, metathesis, epenthesis, consonant deletions (in initial, medial or final positions), syllable deletions (in initial, medial or final positions), cluster reduction.

The phonological processes were categorized into space, timing and whole word errors and their presence or absence in the two groups of participants with DAS and sAOS is shown in table 30. Illustrations as it was evident in participants for each of the processes in DAS and sAOS groups are also provided. From table 30, it is evident there are at least 30 processes identified in the speech samples of children with DAS. Of the 31 processes, amongst sAOS groups, 27 processes were identified in participants with ELD, 29 in participants with PD and 30 processes in participants with autism.

Table 30: Types of phonological processes that were observed in the participant groups.

SNo	Types of phonological processes with examples	Participant groups			
		DAS	ELD	PD	Autism
	I. Space Errors				
1.	*Fronting*				
a.	Fronting of velars Replacement of velars such as /k/, /g/ and /ŋ/ with sounds that are made in a more anterior position, for instance an alveolar / dental / retroflex stop is defined as fronting (Pena-brooks & Hegde, 2000) Examples: Ku:d̪alu → t̪ud̪alu (meaning 'hair')	✓	✓	✓	✓
b.	Fronting of dental / retroflex stops to bilabial stops Replacement of dental / retroflex stops /t/, /d/, /n/, /ɭ/ by bilabial sounds /p/, /b/, and /m/ (Pena-brooks & Hegde, 2000) Examples: d̪aɭimbe→ ma:ɭimbe (meaning pomegranate). Retroflex was also considered because Kannada has retroflex sounds.	✓	✓	✓	✓
2.	*Backing*				
a.	Backing of bilabial stops Substitution of bilabial stops /p/, /b/, /m/ with stops produced further back in the oral cavity like dental, palatal and velar stops (Pena-brooks & Hegde, 2000). Examples: /mane/→[nane] meaning 'house'	✓	✓	✓	✓
	Backing of dental / alveolar stops Substitution of alveolar / dental stops, /t/, /d/, /n/ with stops produced further back in the oral cavity like palatal and velar stops. It is not a commonly occurring process in normal development but observed in children with severe phonological disorders (Pena-Brooks & Hegde, 2000) Example: ga:ɭipata → ga:ɭipaka (meaning 'kite')	✓	✓	✓	✓
3.	*Vowel deviations*				
a.	Vowel centralization Any vowel when changed into the central vowel /ə/ was considered as vowel centralization (Pena-brooks & Hegde, 2000) Example: aɖigemane → aəgemane (Meaning 'kitchen')	✓	✓	✓	✓

SNo	Types of phonological processes with examples	DAS	ELD	PD	Autism
b.	Vowel prolongation Short vowels were prolonged when ever syllable / single consonant deletions occurred.Example: *Syllable deletion:* ba:ɭehannu →baa:nu (meaning banana)	✓	✓	✓	✓
c.	Vowel shortening When long vowels are perceived as reduced in length, it is referred to as vowel shortening (Grunwell, 1997) Example: a:ɭugəɖɖe → alugəɖɖe (meaning potato)	✓	✓	✓	✓
d.	Monophthongization or diphthong reduction Substituting a diphthong to a vowel is defined as monophthongization or diphthong reduction. There was only one opportunity for this error in the whole word list (in the word 'vaid̪ja') [Grunwell, 1997] Example: vaid̪ja → ved̪d̪a (meaning doctor)	✓	✓	✓	✓
e.	Palatalization: The replacement of the alveolar fricative /s/ by the palatal /ʃ/. This process was not seen in DAS group but was present in sAOS group (Grunwell, 1997]. Example: se:bu → ʃe:bu (meaning apple)	--	✓	✓	✓
f.	Depalatalization This is defined as the substitution of an alveolar fricative for a palatal fricative (Pena-Brooks & Hegde, 2000). Example: prəʃne → pəsne (meaning 'question')	✓	--	--	--
	II. Timing errors				
1.	Gliding of laterals (/r/, /l/) Substitution of a glide for a prevocalic liquid (/l/, /r/) is considered as gliding (Pena-Brooks & Hegde, 2000). Examples: t̪əle → t̪əje (meaning 'head')	✓	✓	✓	✓
2.	Stopping Substitution of stops for fricatives and affricates is referred to as stopping. This process is mostly observed in word-initial position (Pena-Brooks & Hegde, 2000). Examples: se:bu → tʃebu (meaning 'apple')	✓	--	✓	✓
3.	Deaffrication of affricates (to fricatives) Replacement of an affricate with a stop or fricative. Stopping of affricates were categorized as stopping in this study (Pena-Brooks & Hegde, 2000). Examples: ʧamaʧa → masa: (meaning 'spoon')	✓	✓	✓	✓

SNo	Types of phonological processes with examples	DAS	ELD	PD	Autism
4.	Affrication of fricatives When an affricate sound is substituted for a fricative it is referred to as affrication (Stoel-Gammon & Dunn, 1985) Examples: pus̪taka → putʃtʃaka (meaning book)	✓	✓	✓	✓
5.	Denasalization of nasal continuants Denasalization of nasal continuants is defined as the replacement of nasals by stops whose place of articulation is similar to the target sound (Bernthal, & Bankson, 1993). Examples: Pennu → pettu (meaning pen)	✓	--	✓	✓
6.	Postvocalic devoicing Post vocalic devoicing is defined as a process when a voiced consonant followed by a vowel become voiceless (Pena-Brooks, & Hegde, 2000). Examples: ga:ɭipata → ka:ɭipata (meaning kite)	✓	✓	✓	✓
7.	Prevocalic voicing When a voiceless sound preceding a vowel is substituted with a voiced sound, it is defined as prevocalic voicing (Pena-Brooks, & Hegde, 2000). Examples: Kannaɖaka → gannataka (meaning glasses)	✓	✓	--	✓
8.	*Others* These processes include those that have not been traditionally reported in the literature for English				
a.	Substitution of singleton consonants for geminated clusters (degemination) This was considered when a geminated cluster lost its geminate quality and was replaced by its singleton counterpart (Ramadevi, 2006) Examples: a:ɭugəɖɖe → a:ɭugəɖe (meaning potato)	✓	✓	✓	✓
b.	Substitution of geminated clusters for singleton consonants (gemination) Substitution of geminate clusters to singleton consonants. Since this process was seen to occur while placing stress on a singleton consonant, it was considered as an atypical phonological process (Rama Devi, 2006). This process showed greater frequency of occurrence in DAS and autistics. Example: huɖugi → huggi (meaning girl)	✓	✓	✓	✓

SNo	Types of phonological processes with examples	DAS	ELD	PD	Autism
	III. Whole word errors				
1.	Cluster reduction This is referred to the substitution of single or all sounds of a cluster. It could be either deletion of a single sound in a cluster, or substitution of all sounds in a cluster by a single sound that was not a member of the target cluster (Stoel-Gammon, & Dunn, 1985). Example: *Retaining one sound in a cluster:* su:rja → su:ja (meaning sun) *Substitution of single consonant to a cluster:* d̪e:vas̪ta:na→ d̪e:vatʃa:na (meaning temple)	✓	✓	✓	✓
2.	Consonant deletion: Omitting singleton consonants anywhere in the word except the final position is referred to consonant deletion (Pena-Brooks & Hegde, 2000). Since words ending with final consonants are not common in Kannada, medial consonant deletion was considered in this study (Hiremath, 1980) Rama Devi (2006) also observed medial consonant deletion in children with hearing impairment aged 5 to 9 years. Example: *Deletion in Initial position:* Pennu → ennu (meaning pen) *Deletion in medial position:* ba:ɭehannu → ba:annu	✓	✓	✓	✓
3.	Epenthesis Insertion of any consonant or vowel in a given word is defined as Epenthesis (Velleman, 1998) Examples: d̪aɭimbe→ and̪abe (meaning pomegranate)	✓	✓	✓	✓
4.	Migration This involves movement of elements from their locations within the adult word. In migration, one element moves elsewhere. (Velleman, 1998). Examples: huɖugi → huguɖi (meaning girl)	✓	✓	✓	✓
5.	Metathesis The complete interchange of elements from their locations within the adult word (Velleman, 1998) is defined as Metathesis. Examples: d̪e:vas̪ta:na→ ve:t̪asta:na (meaning temple)	✓	--	✓	✓

SNo	Types of phonological processes with examples	DAS	ELD	PD	Autism
6.	Consonant harmony These are processes that occur when the consonants (or vowels) within a word become alike or more alike (Velleman, 1998). Although different types such as nasal, labial and velar assimilation are dicussed in literature, in this study, all assimilation processes were considered as consonant harmony. Example: aḏʒigemane → akege (meaning kitchen)	✓	✓	✓	✓
7.	Vowel harmony This occurred when two vowels that are non-adjacent to each other in a word become alike or more alike (Velleman, 1998). Examples: i:ruɭɭi → i:ii (meaning onion)	✓	✓	✓	✓
8.	Reduplication Reduplication is, in a sense, total harmony. It involves repetition of the same syllable. Repetition of a syllable of a target word that resulted in the creation of a multisyllabic word form (Pena-brooks & Hegde, 2000) was noted as reduplication. Examples: d̪a:ɭimbe → ad̪a:d̪e (meaning pomegranate)	✓	✓	✓	✓
9. a.	Substitution of geminated clusters for non-geminated clusters This type of substitution occurs when a geminated cluster replaces a non-geminated cluster. This was again observed by Rama Devi (2006) in her study with hearing impaired children in th eage range 5-9 years. The geminate cluster included either a member from the non-geminate cluster or non-member which is not a part of the cluster itself. Examples: praʃne → patʃtʃe (meaning question) kriʃna → kinna (meaning krishna, a god)	✓	✓	✓	✓
b.	Syllable deletion (Stoel-Gammon & Dunn, 1985) This process refers to the omission of a syllable that is present in the adult form of the word. Since stress is an aspect that is not clearly defined in Kannada, the process 'unstressed syllable deletion' or 'weak syllable deletion' was not considered. Hence, it was considered with respect to position in the word, i.e., initial, medial or final. This process was more common in multisyllabic words				
i.	Syllable deletion in initial position Examples: ga:ɭipata → pata (meaning kite)	✓	✓	✓	✓
ii.	Syllable deletion in medial position Examples: gaḏʒija:ra → ga:jaja (meaning clock)	✓	✓	✓	✓
iii.	Syllable deletion in final position Examples: pus̪taka → putʃa (meaning book)	✓	✓	✓	✓

As seen from the processes listed, it is notable that none of the participants with sAOS showed depalatalization. Errors typical of DAS such as metathesis, vowel errors, stopping and denasalization were evident in speech of participants with PD and autism. Moreover all the groups with sAOS (ELD, PD and Autism) showed unusual error patterns similar to the DAS group. It is evident that participants with autism in sAOS group exhibited maximum number phonological processes (30) similar to participants with DAS when compared to groups with PD (29) and ELD (27). The presence of these phonological processes in DAS has been documented in literature (Shriberg & Kwiatkowski, 1980; Velleman, 1998). Among participants with sAOS, Marili et al. (2004) reported of atypical phonological development with deviant phonological processes and unexpected phonetic repertoires (Wolk & Edwards 1993; Wolk & Giesen 2000) as well as developmental asynchronies in children with Pervasive Developmental Disorder (PDD). However, there are dearth of studies on phonological processes in children with ELD and PD.

Most of the factors influencing phonotactics are said to be production based patterns (Velleman, 1998). The error patterns seen in groups with DAS and sAOS can be correlated with phonotactic patterns of the Kannada language. Acquisition of geminates in kannada speaking children is found to be as early as 12 months of age (Rupela & Manjula, 2006). Numerous occurrences of words with medial geminates are also reported in Kannada (Hiremath, 1980). It is notable from table 30 that the unusual error patterns seen in both the groups is with respect to gemination such as substitution of singleton consonants for geminate clusters, and substitution of geminate clusters for non geminate clusters. There is evidence for such processes in children with hearing impairment in the age range 5 to 9 years as well (Rama Devi, 2006). Participants showing unusual error patterns with respect to gemination also fall in similar age range of 4 to 9 years in this study. Overstressing of syllables or singleton consonants in words results in production of geminated clusters in children with DAS (Shriberg et al., 2001; 2003). Stressing of syllables is also shown by all the participants of sAOS group similar to participants with DAS.

Syllable deletion was considered in terms of position (initial, medial, or final) rather than weak stress or no stress on syllables (weak syllable deletion), because stress is not well defined in Kannada. Also, in terms of processes depicting whole word errors, medial consonant deletion was considered rather than final consonant deletion as words in Kannada ends with open syllables with vowel endings. With respect to clusters, the process, cluster reduction was more evident and frequently occurring in all the participants in groups with DAS and sAOS. This finding was again similar to results found in children with hearing impairment in the age range 5-9 years (Rama Devi, 2006). In terms of processes pertaining to vowels, vowel substitutions in the form of centralization, shortening, prolongations, monophthongization / diphthongization were more frequent in their occurrence, in the speech of DAS and sAOS. Vowel deviations, cluster reduction, metathesis, consonant and vowel harmony, and idiosyncratic / unusual error patterns are defined as characteristic error patterns of children with DAS (Davis, Jakielski, & Marquardt, 1998; Velleman, 2003; Lewis et al., 2004). However, these patterns typical of DAS group were also observed in all the groups with sAOS, viz, ELD, PD and Autism, with autistics showing more similar error patterns as DAS group when compared to ELD and PD. This suggests that participants with sAOS groups exhibit similar phonological errors like those with DAS. The percentage and frequency of occurrence of each of these processes in children with DAS and sAOS would give a clear picture on phonotactics and praxis skills in the participants.

b) Percentage occurrences of phonological processes

All phonological process errors were divided into space, timing and whole word errors. To calculate percentage occurrence of phonological processes it is crucial to determine the total number of opportunities for the use of a specific phonological process in addition to the total number of actual occurrences (Pena-Brooks & Hegde, 2000). Opportunities refers to possible number of occurrence for each process. In this study, opportunities were four and greater for the observed phonological processes except for monophthongization which had only one opportunity in a list of 40 words. Using the following formula, percentage occurrence of error patterns were calculated:

$$\frac{\textit{Actual numbers of occurrences of a process}}{\textit{Potential numbers of occurrences}} \times 100$$

Percentage occurrences were statistically analyzed using One-way ANOVA for comparison across the two groups (DAS and sAOS). A significant main effect of groups was found for most of the phonological processes. It is evident from Table 31 that one-way ANOVA revealed significant differences between the two groups in terms of percentage occurrences of specific phonological error patterns. Duncan's post-hoc test was carried out to determine the groups that differed significantly.

Table 31: Mean percentage occurrences and SDs of phonological processes in groups with DAS and sAOS.

SNo.	Phonological Processes	Percentage occurrences of phonological processes								
		DAS		ELD		PD		Autism		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72
	Space Errors									
1.	*Fronting*									
a.	Fronting of velars	4.86	2.61	2.31	2.04	5.11	3.83	1.13	1.44	4.23**
b.	Fronting of retroflex stops	10.40	3.27	1.66	0.35	1.26	0.11	9.60	4.26	18.33***
c.	Fronting of dental stops to bilabial stops	3.73	2.55	1.54	0.19	1.47	0.45	2.76	1.87	3.12**
2.	*Backing*									
a.	Backing of bilabial stops	1.10	1.01	2.38	0.52	1.02	0.91	1.31	1.83	1.87
b	Backing of dental stops	1.21	0.72	2.14	1.97	1.56	0.93	1.96	1.20	2.21
3.	*Vowel Deviations*									
a.	Vowel centralization	16.85	6.35	7.16	3.33	6.88	2.43	7.55	5.10	4.27**
b.	Vowel prolongation	4.79	2.40	1.10	1.12	1.51	0.62	1.06	0.78	3.85**
c.	Vowel shortening	6.13	0.32	1.82	0.73	1.13	0.33	3.23	1.73	1.76
d.	Monophthongization	43.00	19.23	19.67	15.23	14.54	7.56	33.45	20.46	8.57***
4.	Palatalization of alveolar fricative /s/	0.00	0.00	11.11	9.93	3.70	5.73	3.17	5.42	5.34*
5.	Depalatalization	11.13	4.32	4.83	1.73	4.66	2.23	9.13	3.68	7.38***
	Timing Errors									
6.	Gliding of laterals (/r/, *IV)*	2.47	2.48	1.29	0.45	0.44	0.48	0.88	1.97	0.71
7	Stopping	10.79	6.07	0.00	0.00	2.08	2.92	2.78	1.88	4.79**
8.	Deaffrication of affricates (to fricatives)	44.66	35.33	27.66	27.32	16.66	19.66	37.00	30.55	2.41*
9.	Affrication	3.82	3.15	0.29	0.46	3.12	5.52	2.16	2.17	0.97
10.	Denasalization	6.25	8.82	0.00	0.00	5.83	5.84	5.00	7.07	1.15
11.	Nasalization	2.63	3.12	1.37	1.40	1.54	1.81	1.76	2.95	0.02
12.	Postvocalic devoicing	6.16	2.02	4.16	1.67	5.16	3.92	6.22	2.62	1.02
13.	Prevocalic voicing	1.73	1.33	0.98	1.51	0.00	0.00	0.42	1.11	0.80
14.	*Others*									
a.	Substitution of singleton consonants	9.251	13.26	7.40	5.731	9.25	8.36	4.76	5.93	0.35

	for geminate clusters (degemination) #									
b.	Substitution of geminate clusters for singleton consonants or non clusters (gemination) #	5.19	1.47	4.76	3.90	2.85	1.80	4.48	6.97	1.62
15.	Lateralization#	0.78	1.23	0.85	0.76	0.42	0.46	0.48	0.96	0.32
	Whole Word Errors									
16.	Consonant cluster reduction	46.05	11.07	38.59	17.97	30.70	19.45	39.32	21.87	0.10
17.	*Consonant Deletion*									
a.	Initial consonant deletion	16.23	7.11	8.55	6.96	8.55	5.51	10.57	6.09	3.59**
b.	Medial Consonant deletion	15.68	12.14	9.19	6.07	8.67	6.22	13.33	8.35	2.34
18.	Epenthesis	6.06	3.31	2.99	1.59	3.13	1.28	4.09	2.17	2.17
19.	Migration	11.63	5.28	3.70	1.72	4.13	1.88	6.97	3.59	3.80**
20.	Metathesis	8.35	4.33	0.00	0.00	0.56	9.44	0.12	0.32	4.42**
21.	Consonant harmony	3.06	1.28	1.13	1.16	2.56	1.43	1.70	2.74	0.74
22.	Vowel harmony	4.35	2.33	3.33	2.45	3.12	1.89	3.79	1.52	1.10
23.	Reduplication	4.66	3.22	1.28	0.44	0.28	0.44	1.48	0.67	2.98*
24.	*Others*									
a.	Substitution of geminate clusters for non-geminate clusters#	3.77	2.25	6.25	2.42	4.68	3.95	2.23	1.77	2.74
b.	*Syllable Deletion*									
i.	Syllable deletion (initial position)#	7.92	8.04	5.47	3.22	4.10	2.62	5.95	3.69	2.75
ii.	Syllable deletion (medial position)#	21.85	14.53	15.67	10.34	6.23	3.87	19.56	12.66	3.64*
iii.	Syllable deletion (final position)#	5.67	3.46	6.45	3.99	4.60	2.56	5.69	3.14	2.17

Note: *** p< .001, ** p< .01, * p< .05;   # - Unusual error patterns

Processes such as pre-vocalic voicing, vowel distortion, nasalization and backing did not show significant difference between groups. This could be because the percentage and frequency of occurrence of these processes were too less in the participants from both the groups and hence the negligible difference. Apart from them, there were a few more processes such as gliding, affrication, lateralization, and consonant harmony that did not show significant difference due to high variability with in groups which is evident from the high standard deviation values.

However, other processes like consonant cluster reduction, epenthesis, vowel harmony, medial consonant deletion and unusual error patterns such as substitution of geminate clusters for non-geminate clusters, substitution of singleton consonants for geminate or non-geminate clusters, syllable deletion (in initial and final positions), did not reveal significant difference because participants from all the groups had shown similar percentage of occurrences for these processes. Since non-geminate clusters are acquired by the age of four (Rupela & Manjula, 2006) and largely in use by children of that age, there is a predominant use of unusual error patterns such as substitution of geminate clusters for non-geminate clusters, substitution of singleton consonants for geminate or non-geminate clusters. However, the mean values in table 31 shows frequent occurrence of these processes in DAS group compared to sAOS group. The presence of unusual error patterns could serve as evidence for presence of similar phonological errors suggestive of DAS in participants with sAOS.

To determine the groups that significantly differed, Duncan's post hoc test was carried out and following inferences can be drawn:

- ✓ Most of the *space error patterns* constituting fronting, vowel deviations (specifically vowel centralization and prolongations), monophthongization, depalatalization and palatalization except backing and vowel distortion showed significant difference between children with DAS and sAOS groups. Among these space error patterns, DAS group showed maximum errors for all the processes except palatalization which was not observed for participants with

DAS. Palatalization was seen only for participants in sAOS groups, with ELD showing maximum errors compared to PD and autism.

- ✓ *Timing error patterns* such as stopping and deaffrication were significantly different between the DAS and sAOS groups, with DAS showing greater error patterns compared to participants with sAOS.
- ✓ Among *whole word errors*, Syllable deletion (in medial position), Initial Consonant Deletion, Migration, Metathesis, and Reduplication were significantly different between DAS and sAOS group. The process of syllable reduplication (Kent, 1984) observed in early spoken vocabularies of young children suggests an interaction between speech motor pattern and language acquisition. It is also of clinical significance to note that persistence of such reduplication is suggested as a sign that a child is at risk for delays in expressive language development (Ingram, 1976).

It was observed that the process, consonant cluster reduction was maximum in all the groups followed by deaffrication which is a form of consonant substitution. The most consistent finding of Thoonen et al (1997) in their study was the higher percentage of singleton consonant substitutions, omissions, distortions, and consonant cluster reductions, in DAS children than for the typically developing group. The most frequent consonant errors observed were substitutions and cluster reductions. High consonant substitution rates in DAS was also reported by Aram and Glasson (1979), Crary, Landess and Towne (1984), and Jackson and Hall (1987). The consonant errors of the DAS group are akin to descriptions in literature (Thoonen et al., 1997). The percentage occurrences of errors were also similar in participants with sAOS. A characteristic feature of DAS is vowel substitutions (Davis & Velleman, 2000), specifically vowel centralization which are significantly more in the DAS group than sAOS groups. Participants with sAOS also showed predominant use of vowel centralization compared to other vowel deviations like prolongation and shortening. Strand (2003) recommended characteristics such as restricted sound inventories and especially distorted vowels or a single centralized vowel sound as possible indicators of motor planning and motor programming difficulties, in young children with DAS.

The above findings should however be cautiously interpreted as the significant difference was not observed between participants with DAS and all the participants in the suspected apraxic group. It is notable that the differences for most of the processes observed in participants with DAS as compared to that of PD or ELD groups were significant. Group with DAS did not differ significantly from autism group except for the error pattern of metathesis. This shows that the phonological error patterns were more similar across participants with DAS and autism followed by those with ELD and PD.

There was no significant difference revealed in terms of error types (space, timing and whole word errors) with in the groups. However DAS exhibited higher percentage of whole word errors and timing errors followed by space errors. Likewise, in sAOS group, participants with ELD, PD and autism exhibited a similar trend in terms of error patterns, with higher percentage of whole word errors and timing errors followed by space errors. However, the various phonological errors were higher in DAS group than sAOS group. Presence of whole word and timing errors are more common in children with DAS when compared to space errors (Velleman, 2003). There were more whole word and timing errors when compared to space errors in participants with sAOS and this supports breakdown in praxis control.

The other errors such as fronting, vowel deviations, stopping, unusual errors and others, are particularly indicative of DAS especially when they are identified in children above the age of 3 (Velleman, 2003; Bleile, 2004) and these errors were found in DAS group. The three types of phonological error patterns, viz, space, timing and whole word errors, are reported to be more indicative of underlying processing deficit. Spacing errors are attributed to decreased oral awareness and position of the articulators, which in turn result in decreased precision and overshooting in order to receive adequate sensory feedback (Velleman, 2003). Velleman hypothesized that timing errors are indicative of deficient motor planning with respect to timing. Although there is variability in terms of percentage occurrence of errors in participants with DAS and sAOS, all the participants with ELD, PD and Autism did show the presence of typical phonological errors indicative of DAS in their speech. Presence of similar phonological errors in participants with DAS and sAOS are more indicative of co-occurring praxis deficits in participants with sAOS (ELD, PD and Autism).

In order to evaluate the type of phonological process that is frequently used by the two groups, the frequency of occurrence of each process produced by the participants were also computed.

c) Percentage of persons exhibiting various phonological processes:

The percentage of persons exhibiting various phonological processes was calculated as follows:

$$\frac{\textit{No. of participants in a group exhibiting the process}}{\textit{Total number of participants in the group}} \times 100$$

To compare this score across groups with DAS and sAOS, 'Uncorrelated Equality of Proportions' was applied. The results are tabulated in table 32. In table 32,' 1' represents participants with DAS, '2' represents participants with ELD, '3' represents participants with PD, and '4' represents those with Autism. Also,'-' indicates that values of two groups are equal, and hence no test is required.

Table 32: Uncorrelated equality of proportions comparing the frequencies of phonological processes in terms of space, timing, and whole word errors used by the participants with DAS and sAOS.

Phonological processes	z12	z13	z14
Space Errors			
Fronting of velars	-	1.10	2.29*
Fronting of retroflex stops	1.73	2.45*	1.08
Backing of bilabial stops	2.45*	2.36*	0.41
Backing of dental stops	2.36*	3.10*	0.59
Vowel centralization	-	-	-
Vowel prolongation	1.20	1.90	1.07
Vowel shortening	0.76	3.58*	0.14
Monophthongization or diphthong reduction	-	-	-
Palatalization of alveolar fricative /s/	2.45*	-	1.08
Depalatalization of palatal fricative /ʃ/	11.49*	1.90	1.70
Timing Errors			
Gliding of laterals (/r/, /l/)	1.04	r 0.33	1.34
Stopping	4.90*	0.68	0.41
Deaffrication of affricates (to fricatives)	0.76	1.44	1.88

Affrication of fricatives	2.27*	0.76	0.59
Nasalization	3.46*	3.46*	0.30
Denasalization of nasal continuants	4.56*	1.04	0.41
Postvocalic devoicing	2.00*	0.36	0.17
Prevocalic voicing	0.36	1.04	0.59
Lateralization	1.04	2.00*	0.59
Substitution of singleton consonants for geminate clusters (degemination)	0.69	.00	0.30
Substitution of geminate clusters for singleton consonants (gemination)	0.35	1.20	2.27*
Whole Word Errors			
Consonant cluster reduction	-	-	-
Initial consonant deletion	1.73	3.46*	1.67
Medial Consonant deletion	-	1.10	1.08
Epenthesis	1.20	1.20	1.07
Migration	-	-	-
Metathesis	11.49*	0.49	5.01*
Consonant harmony	1.20	0.49	1.70
Vowel harmony	1.20	0.49	1.70
Reduplication	1.04	2.93*	0.66
Substitution of geminate clusters for non-geminate clusters	-1.04	1.20	0.39
Syllable deletion	1.73	1.10	-
Syllable deletion in initial position	1.73	1.44	1.67
Syllable deletion in medial position	1.04	2.00*	1.70
Syllable deletion in final position	0.36	1.04	0.59

*p>1.96 shows significant difference between the groups.
1.96 is the standard normal table value at a significance level of 5%.

Uncorrelated equality of proportions shows that the processes / phonological error patterns marked with asterisk '*' are significantly different in terms of frequency of occurrence between groups with DAS and sAOS (ELD, PD and Autism). Column zl2 in Table 32 shows the differences in terms of frequency of occurrence of various processes between children with DAS and ELD. The two groups (DAS and ELD) demonstrated significant difference for processes such as backing, palatalization (more frequent in ELD), depalatalization, stopping, affrication, nasalization, denasalization, post vocalic devoicing and metathesis (with greater frequency of occurrence in DAS group). Column zl3 demonstrates the difference in frequency of use of phonological processes between children with DAS and PD. The significant difference was observed for processes such as backing, fronting of retroflex stops, vowel shortening, nasalization, lateralization, initial consonant deletion, reduplication, and syllable deletion in medial position between DAS and PD. The difference in frequency of occurrence for processes between children with DAS and autism are shown in column zl4. Fronting of velars, gemination (substituting geminate clusters for singleton consonants), and metathesis showed significant difference in terms of its frequency of occurrence between DAS and participants with autism.

The group with DAS generally exhibited higher frequency of use of phonological processes when compared to the sAOS groups. On the whole, it is notable that processes indicative of apraxia such as metathesis, post vocalic devoicing, affrication, depalatalization, nasalization are frequently used by participants with DAS compared to ELD, PD and autism. This suggests that the frequency of use of phonological processes is often greater in children with DAS when compared to sAOS groups.

However, on careful observation, it is evident that other processes associated with omissions such as consonant cluster reduction, consonant deletion in different positions, syllable deletions in different positions, processes associated with consonant and vowel substitutions such as deaffrication, vowel centralization, vowel shortening, vowel prolongation and processes related to sequencing difficulty such as migration, epenthesis, reduplication, consonant and vowel harmony (Hall, Jordan, & Robin, 1993; David, Jakielski & Marquardt, 1998) are used more frequently even by other groups with sAOS such as autism, PD and ELD. The presence of unusual error patterns or idiosyncratic errors are reported to be characteristic of children with phonological disorders (Bernthal & Bankson, 1993). These are often not typical of normal development (Edwards & Shriberg, 1983; Stoel-Gammon, & Dunn, 1985). High variability, addition errors, vowel errors, and consonant deletion in the initial position were referred to as atypical errors in participants with DAS (Davis, Jakielski & Marquardt, 1998; Lewis et al., 2004). Since these processes are also indicative of developmental apraxia of speech and there is no significant difference revealed in terms of their frequency of occurrence between groups with DAS and sAOS, it is probable that groups with ELD, PD and Autism also exhibit co-occurring features of DAS.

Processes such as denasalization and nasalization or in general, hypernasal speech quality were observed by many investigators in children with DAS (Yoss & Darley, 1974; Aram & Glasson, 1979; Bowman, Parsons, & Morris, 1984; Parsons, 1984; Hall, Jordan, & Robin, 1993). Velleman (2003) considers presence of nasality to be a sign of dysarthria. Children with autism did show both nasalization and denasalization similar to DAS group unlike PD group which showed more of denasalization although there was a high variability within these groups. ELD group showed comparatively minimal usage of these processes.

The frequency of occurrence of space errors, timing errors and whole word errors are depicted in Figures 17, 18 and 19, respectively. As evident from figure 17, almost all the phonological processes except palatalization occurred in greater than 50% of participants with DAS. Backing of dental stops was least frequent in DAS group followed by backing of bilabial stops. Most frequently occurring space error patterns were fronting of velars and retroflex sounds, vowel deviations, monophthongization and depalatalization. These errors typical of DAS were observed in more than 50 % of participants with sAOS, viz, ELD, PD and autism.

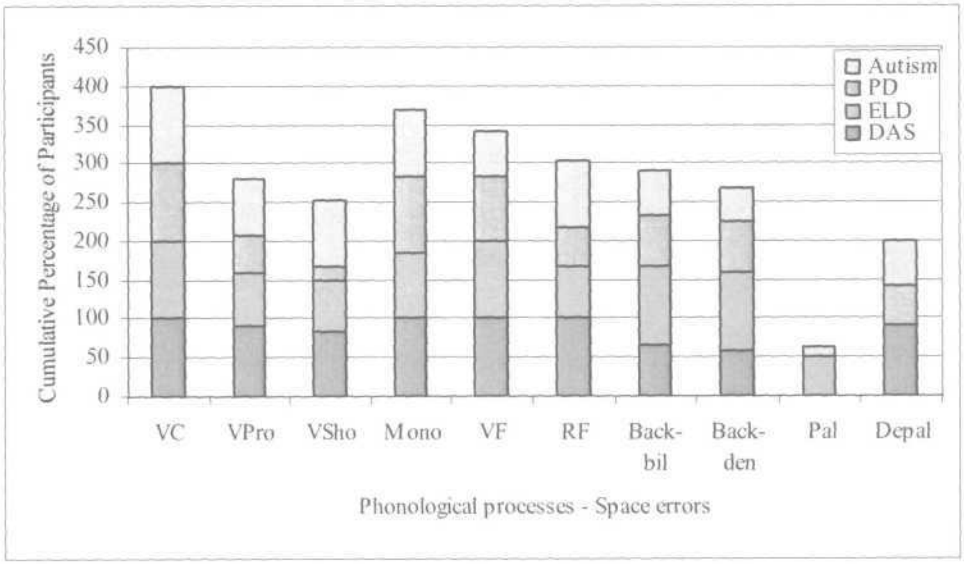

Figure 17: Frequencies of persons exhibiting space errors from two groups of participants with DAS and sAOS

VC- Vowel centralization	RF- Fronting of retroflexes
Vpro-Vowel Prolongation	VF-Velar Fronting
Vsho- Vowel shortening	Back-Bil- Backing of Bilabials
Mono-Monophthongization	Back-Dent-Backing of dentals
Pal-Palatalization	Depal-Depalatalization

Timing errors were also more frequently observed in participants with DAS and sAOS. Figure 18 depicts the frequencies of persons from the three groups of participants that exhibit different phonological processes in terms of timing errors. Timing errors such as stopping, affrication, deaffrication, gemination, nasalization, devoicing, post vocalic voicing, typical of participants with DAS occurred in more than 50% of the individuals with sAOS similar to those with DAS. While low frequency of occurrence was seen for denasalization in sAOS groups, 50% of participants with DAS exhibited this error pattern.

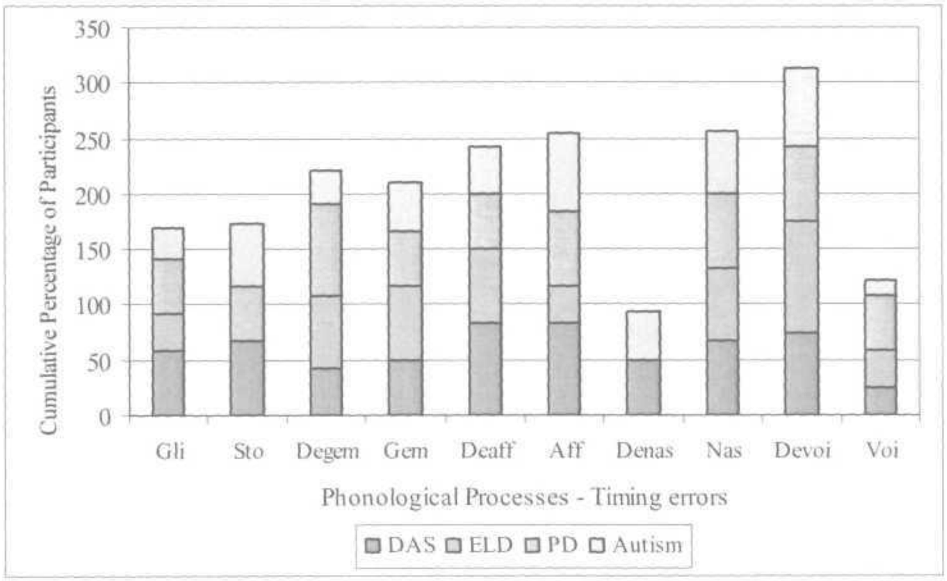

Figure 18: Frequencies of persons exhibiting timing errors from two groups of participants with DAS and sAOS

Gli-Gliding	Deaff- Deaffrication
Sto-Stopping	Aff- Affrication
Degem- Degemination	Nas- Nasalization
Gem- Gemination	Denas -denasalization
Voi-Prevocalic Voicing	Devoi- Postvocalic Devoicing

Figure 19 depicts the frequencies of participants exhibiting different phonological processes in terms of whole word errors from the two groups of participants. Greater numbers of participants with DAS and sAOS exhibited the different whole word errors. Similar to those with DAS, more than 50% of participants with sAOS exhibited phonological processes such as, initial consonant deletion, consonant deletion in the medial position, epenthesis, metathesis, reduplication, syllable deletion in initial, medial and final positions and c'v.ster reduction.

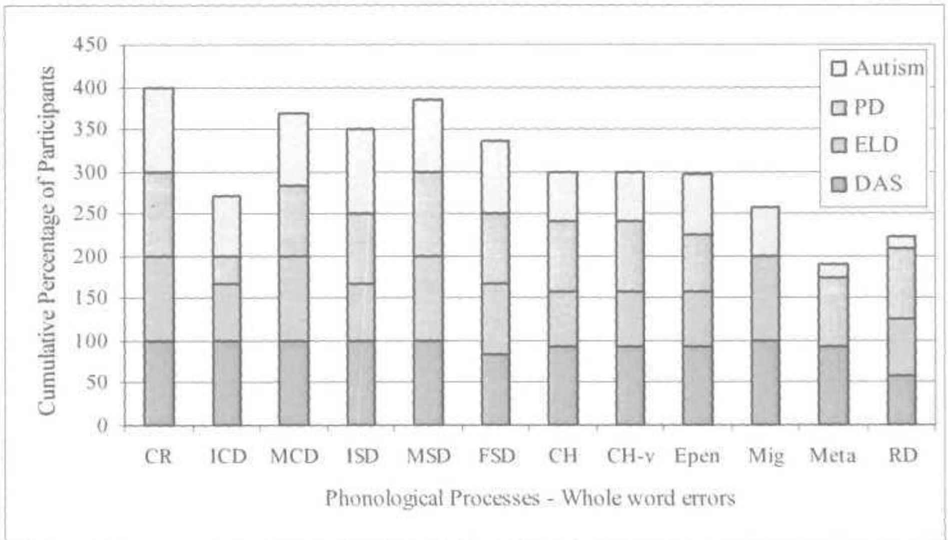

Figure 19: Frequencies of persons exhibiting whole word errors from two groups of participants with DAS and sAOS

CR-Cluster Reduction	CH- Consonant Harmony
ICD- Initial Consonant Deletion	Epen- Epenthesis
MCD- Medial Consonant Deletion	1SD- Initial Syllable Deletion
Mig- Migration	MSD- Medial Syllable Deletion
Meta-Metathesis	FSD- Final Syllable Deletion
CH-v- Vowel harmony	

Thus from word level assessment, it is evident that group with DAS exhibited greater number of phonological processes in terms of percentage and frequency of occurrence. There were only a few processes that were significantly different between groups with DAS and sAOS. Other phonological processes that serve as definite indicators of DAS are exhibited even by participants with sAOS. Those include higher percentage occurrence of error patterns of omission, voicing errors, sequencing difficulty, nasalization, vowel substitutions, idiosyncratic errors or unusual error patterns. There was no significant difference for most of these processes between groups with DAS and sAOS, indicating the co-occurrence of verbal praxis deficit in children with ELD, PD and Autism, similar to participants with DAS. The fact that there were limited number of participants in each of these experimental groups and were heterogeneous in their responses renders less scope for generalization. Heterogeneity can be observed from high standard deviation values and not all the participants exhibited these different types of errors to the same degree. A few more errors indicative of apraxia, other than phonological processes were observed and these were evaluated in children with sAOS and DAS group. They are discussed in the following sections.

2) Groping, Disfluencies, Distortion, & Weak Precision

Errors other than phonological processes such as groping, disfluencies etc. were also observed in participants with sAOS and DAS, during the word imitation task. The speech samples of participants with DAS and those with suspected apraxia were evaluated for the presence of groping errors, dysfluencies, distortions, and weak precision of articulators in words of increasing syllable lengths. While groping errors and disfluencies were computed per word, distortions and weak precision in articulation were calculated per consonant in the words. The raw scores were statistically analyzed using One-way ANOVA. The results are tabulated in Table 33 and the means are depicted in Figure 20.

Table 33: Mean and SDs of Groping Disfluencies, Distortion and Weak precision for groups with DAS and sAOS.

Other errors	Groups	Mean	SD	F value
Groping	DAS	16.54	6.50	13.180***
	ELD	0.00	0.00	
	PD	0.34	0.21	
	Autism	1.57	0.98	
Disfluencies	DAS	3.00	2.68	0.847
	ELD	2.00	3.09	
	PD	2.83	2.56	
	Autism	1.14	1.86	
Distortion	DAS	12.86	3.45	1.507
	ELD	9.57	3.98	
	PD	11.60	2.45	
	Autism	12.12	2.24	
Weak Precision of articulators	DAS	32.27	5.38	2.011
	ELD	28.66	6.34	
	PD	25.16	10.36	
	Autism	23.00	11.26	

*** - $p<0.001$

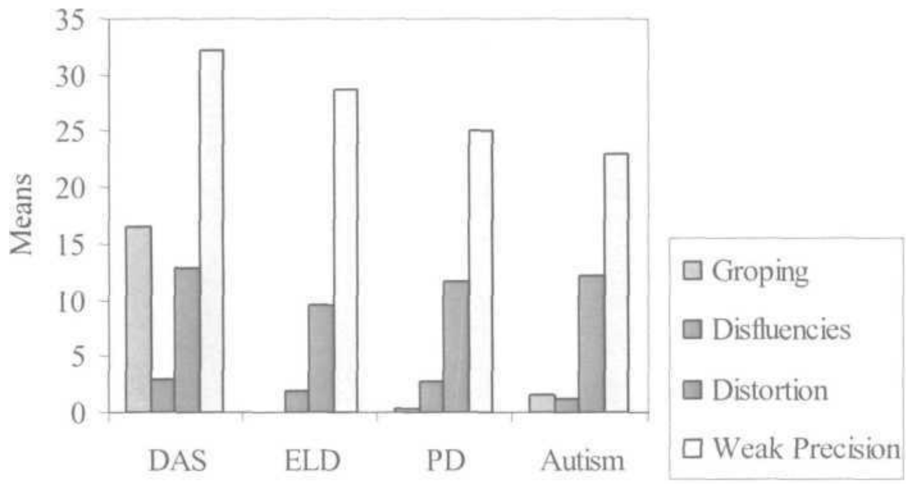

Figure 20: Means of other errors in participants with DAS and sAOS

a) Groping

Results of group comparison using One-way ANOVA shows that participants with DAS and those with suspected apraxia are significantly different in terms of groping behavior. This suggests that groping is a characteristic feature of DAS and is possibly a differential diagnostic marker. It was maximally seen in DAS group and was negligible in those with sAOS. Groping or silent posturing of articulators has also been reported as a most distinctive feature in children with apraxia (Murdoch, Porter, Younger & Ozanne, 1984; Stackhouse, 1992; Crary, 1993; Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Ozanne, 1995; Shriberg, Aram, & Kwiatkowski, 1997a, 1997c; Forrest & Morrisette, 1999; Strand & Mc Cauley, 2000; Hall, 2000a; ASHA, 2002; Nijland et al., 2003; Smit, 2004; Lewis et al., 2004).

b) Disfluencies

Although disfluencies were present in participants with DAS, and sAOS groups, they did not reveal any significant difference. From the mean scores in Table 33, it is seen that greater disfluencies are evident in participants with DAS when compared to sAOS groups. In sAOS groups, greater disfluencies were observed in group with PD followed by those with ELD and autism. The disfluent behaviours observed in these groups were inaudible pauses, part word and syllable repetitions, and prolongations. While more than 90% of participants with DAS showed disfluent behaviour nearly 60% of participants with PD and autism exhibited disfluencies. Only 50% of participants demonstrated disfluencies in ELD group. Disfluency is often cited as a symptom of dyspraxia and a few investigators argue the possibility of co-existence of stuttering and dyspraxia (Kent, 2000; Hammer, 2002).

Disfluencies are reported to indicate "overload" in the system when the demands for speech motor complexity appear greater than the individual's capacity to handle them. Yoss and Darley (1974) suggested that stuttering as well as articulation difficulties might be expressions of developmental apraxia. Both stuttering and apraxia "have been defined or studied in terms of speech motor control dysfunction" (Kent, 2000) and there are controversies regarding this issue. Children who stutter and those who have "ordinary" phonological disorders are also presumed to show some features of DAS (Byrd & Cooper, 1989; Shriberg, Aram & Kwiatkowski, 1997a; McCabe, Rosenthal & McLeod, 1998). Phonological disorders and stuttering are also reported to co-occur in children (St Louis et al, 1991; Conture et al., 1993; Wolk et al., 1993; Bernstein Ratner, 1995; Paden & Yairi, 1996; Yaruss & Conture, 1996; Ratner, 1998; Louko et al., 1999; Melnick & Conture, 2000). The findings of this study point to disfluencies in children with sAOS similar to those with DAS and there is no significant difference evident between the two groups. It is probable that disfluencies are co-occurring features in DAS and sAOS and suggestive of a dysfunction in speech motor control.

c) ***Distortion***

Distortion errors have been reported for children with DAS and is also considered as a diagnostic feature by some (Williams, Ingham, & Rosenthal, 1981; Shriberg, Aram & Kwiatkowski, 1997a, 1997b; Strand, 2003). Statistical analysis using one-way ANOVA did not reveal significant differences across the groups in terms of distortion errors. The DAS group exhibited greater distortion errors followed by those with autistics compared to the other two groups with ELD and PD. Children with apraxia are reported to produce more of distortions or substituted distortions (Robin, 2002) and it is considered as a predominant error type subsequent to substitutions (Itoh & Sasanuma, 1984; Thoonen et al, 1997). Distortions are considered as speech symptoms resulting from deficits in motor-planning. Sound distortions are presumed to result from an inability to make necessary adaptations in movements, to synchronize the movements of the different articulators, to centrally monitor the parameters of all the necessary movements and to keep these parameters within the limits of equivalence (Van der Merwe, 1997). Vowel distortions were also observed in children with DAS in this study unlike its absence in sAOS groups with ELD, PD and autism.

d) Weak Precision

Weak precision was maximally observed in children with DAS followed by those with ELD, PD and autism. This could be attributed to mild tone deficits evident in these groups. Hypotonia is also indicative of dysarthric component. There was no significant difference revealed between the groups in terms of weak precision of articulators.

Along with errors such as groping, dysfluency, distortion and weak precision of articulators and various phonological error patterns, sequence maintenance score was also calculated to evaluate sequencing difficulties with increase in complexity of the word.

The complexity was varied in terms of length of the word that increased with increasing number of syllables.

3) Syllable Sequence measured using Sequence Maintenance Score (SMS)

Sequencing difficulties are reported as an essential characteristic feature of participants with DAS (Forrest, & Morrisette, 1999; Whitebread, Dvorak, & Jakielski, 1999; Hall, 2000a; ASHA, 2002; Marquardt, Sussman, Snow & Jacks, 2002). Inability to maintain sequence is considered to result from poor motor control due to difficulty in planning, co-ordinating and transition of motor speech movements during speech production (Crary & Anderson, 1991; Pollock, & Hall, 1991; Stackhouse, 1992; Velleman & Strand, 1994, 1995; Davis, Strand, & Velleman, 1998). Sequencing difficulties were also reported in children with autism.

The sequence maintenance score (SMS) was calculated for each of the 40 words of increasing syllable lengths, imitated by the participants. This score was evaluated separately for bisyllabic and trisyllabic words using a 3-point rating scale of 0 to 2, based on the numbers of syllables repeated in the correct order (Refer Appendix 2). The raw scores were subjected to statistical analysis using one-way ANOVA. A significant main effect of groups were noticed. Table 34 and figure 21 depict results of sequence maintenance score at word level.

Table 34: Means, SDs and F values of sequence maintenance score at word level for groups with DAS and sAOS

Sequence Maintenance Score for Words	Groups	Mean	SD	One way ANOVA values (F value)
SMS	DAS	27.58	3.37	73.055***
	ELD	63.00	3.44	
	PD	55.50	5.35	
	Autism	51.28	4.94	
SMS - Disyllables	DAS	12.67	3.14	31.103***
	ELD	25.67	1.86	
	PD	25.00	3.41	
	Autism	23.57	4.61	
SMS - Trisyllables	DAS	9.58	2.68	43.750***
	ELD	25.67	1.51	
	PD	19.17	3.25	
	Autism	19.86	4.14	
SMS - Multisyllables	DAS	5.33	1.72	56.085***
	ELD	16.33	1.37	
	PD	11.33	1.75	
	Autism	7.86	2.12	

***-p<0.001

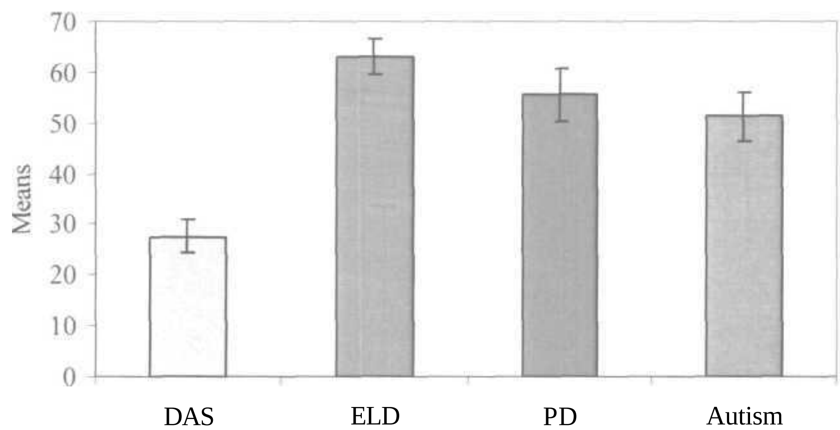

Figure 21: Means and SDs for sequence maintenance score at word level

Group comparison using one-way ANOVA revealed significant difference between participants with DAS and suspected apraxia of speech. The scores were significantly lower in children with DAS when compared to participants in group II suggesting severe sequential deficit in DAS group. They were followed by participants with autism, PD and ELD having relatively better scores. However participants in group II (sAOS) also exhibited sequencing errors for words assessed.

Duncan's post hoc analysis revealed significant difference between groups with DAS and sAOS. In sAOS groups, groups with PD and autism significantly differed from those with ELD. For a total score of 80, raw scores of DAS group ranged from 15 to 39. This shows that all the children with DAS exhibited severe sequencing difficulty. Raw scores of PD and autism groups ranged from 49 to 62 and 38 to 58 respectively. These scores are also indicative of sequential deficit in groups with PD and autism. Unlike other groups with sAOS, scores of participants with ELD ranged from 55 to 71. This shows that there were participants with ELD performing better on sequence maintenance in words. The autistic group showed severe sequencing deficit followed by those with PD and ELD. Hence the sAOS groups are also seen to exhibit praxis deficit but with less severity compared to DAS. Results obtained from this part of the word level praxis assessment gives an insight into the sequencing errors exhibited by the groups with sAOS indicating co-occurring praxis deficits. However, groups with sAOS showed variability in their performances implying heterogeneity with in the group.

When SMS was compared with in groups to see the effect of increase in complexity (with increasing syllable lengths), it was found that in participants with DAS, autism and PD, there is a significant lowering of scores with increase in syllable length from bisyllables to multisyllables and hence the significant difference. Where as in participants with ELD, although there was a lowering of sequence maintenance scores with increase in complexity, it did not reveal a significant difference. Overall, there is poor sequence maintenance observed in children with autism, PD and ELD suggesting the co-occurrence of praxis deficit in these children.

Word level assessment revealed supportive evidences for the presence of co-occurring verbal praxis deficit in children with autism, PD and ELD, similar to those with DAS. The performances were compared against the reference group DAS showing evident praxis deficit. The phonological processes indicative of developmental apraxia of speech were also observed in children with sAOS. Further, other praxis errors such as groping, disfluencies and distortions were observed in participants with group II (sAOS) as well. Additionally, sequence maintenance score was calculated for each word based on a rating scale, the results of which indicated poor sequencing in children with autism and PD when compared to ELD. However not more than two children with ELD (33%) exhibited better scores for sequencing in the higher range. The sequential errors were also found to increase with increase in syllable lengths in groups with sAOS similar to that observed in DAS. Although there was variability observed with in the groups with sAOS, the findings in word level task demonstrates the presence of verbal praxis deficit in children with autism, PD and ELD, probably with varying degree of severity compared to

DAS. Further support is drawn from the analysis of complex tasks using sentences, increasing in syllable length.

D) Sentence level praxis assessment

This assessment included a list of ten sentences with increasing length ranging from three to twelve syllables. One syllable was added to each consecutive sentence to increase the syllable length. The sentences were prepared in Kannada language and ten 'most familiar' sentences were selected for the final protocol based on familiarity rating by 4 to 5 year old typically developing children and they were checked by a linguist for dialectal appropriateness. The participants were asked to imitate the ten sentences after the investigator. The responses were transcribed using the broad IPA system of transcription. The transcribed responses were scored using Percentages of Consonants Correct (PCC), Percentages of Vowels Correct (PVC) metric (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997) and sequence maintenance score using a rating scale of 0 to 2 with 2 indicating higher scores. This rating was based on the number of words repeated in the proper order by the participants. The results are presented under following three sections:

1. Percentage of consonants correct (PCC)
2. Percentage of vowels correct (PVC)
3. Sequence maintenance score

a) Percentage of Consonants Correct (PCC)

In an attempt to provide a more objective measure of severity of impairment, a metric system was developed by Shriberg and Kwiatkowski (1982) that considers the percentage of consonants correct (PCC) as an index of degree of impairment. Shriberg and Kwiatkowski (1982) provided the following scale to determine the severity level of the disorder:

- >85-<100% Mild
- >65- <85% Mild - Moderate
- >50- <65% Moderate - Severe
- <50% Severe

The 'Percentages of Consonants Correct' (PCC) was calculated using the following formula:

$$PCC = \frac{\text{Total numbers of consonants produced correctly}}{\text{Total numbers of consonants attempted}} X100$$

One-way ANOVA was carried out on the scores obtained by the two groups (DAS and sAOS). Table 35 and figure 22 depict the results for the PCC metric at sentence level.

Table 35: Means, SDs and F values for PCC scores in sentences.

Verbal praxis assessment- sentence level	Groups	N	Mean	SD	F(3, 27)= 'F' value	Severity
Percentage of consonants correct	DAS	12	54.09	24.22	0.723	Mod - Sev
	ELD	6	60.06	16.38		Mod - Sev
	PD	6	70.03	14.12		Mild -Mod
	Autism	7	64.14	29.69		Mod - Sev

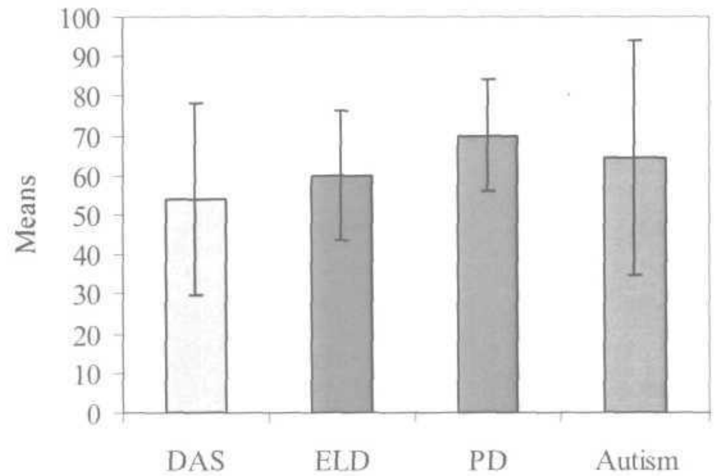

Figure 22: Means and SDs of PCC scores at sentence level

One way ANOVA did not reveal any significant difference between the groups I (DAS) and II (sAOS). While the PCC ranged from 7% to 82% for DAS, in sAOS group, scores ranged from 20% to 88% for participants with autism, 41% to 84% for those with ELD and 50% to 89% for PD group. None of participants with sAOS attained more than 90% scores, similar to the trend observed for participants with DAS. The results however, indicate variability in responses as evident from standard deviation values. The scores were very poor for DAS followed by those with ELD, autism and PD in sAOS groups and there was no significant difference observed between these groups.

When rated based on the scale given for severity as recorded in Table 35, it was found that groups with DAS, autism, and ELD exhibited moderate to severe deficit and PD group showed mild to moderate level of severity. The results thus support the co-occurrence of DAS features in sAOS groups. There is dearth of studies reporting PCC scores in apraxic children for sentences unlike for conversation.

b) Percentage of Vowels Correct (PVC):

Using similar criteria as that used to analyze consonants, the total number of vowel errors were tallied from the transcribed samples and the percentage of vowels correct (PVC) was calculated as follows:

$$PVC = \frac{\underline{\text{Total numbers of vowels produced correctly}}}{\text{Total numbers of vowels attempted}} X100$$

One-way ANOVA was carried out to compare the scores obtained by the two groups (DAS and sAOS) to find the significant main effect of groups. Means, SDs and F values for the PVC scores in the participants from the two groups are depicted in table 36. Figure 23 depicts the means and standard deviations for the two groups of participants.

Table 36: Means, SDs and F values for PVC scores at sentence level

Verbal praxis assessment- sentence level	Groups	N	Mean	SD	F(3, 27)= 'F' value	Severity
Percentage of vowels correct	DAS	12	67.79	13.96	0.913	Mod - Sev
	ELD	6	71.87	16.64		Mild -Mod
	PD	6	84.46	6.49		Mild -Mod
	Autism	7	74.21	19.83		Mild -Mod

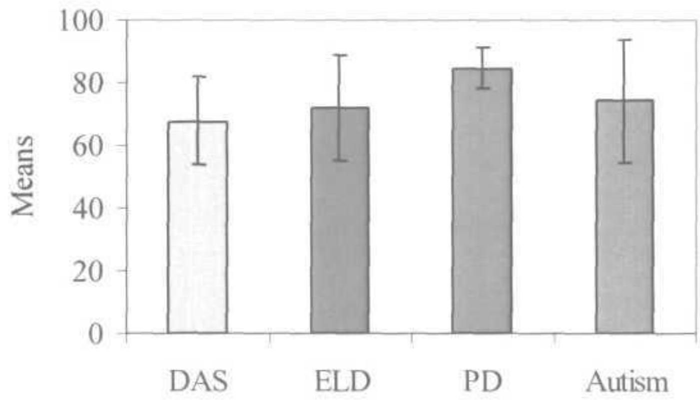

Figure 23: Means and SDs of PVC scores at sentence level

One way ANOVA did not reveal any significant difference between the groups. However, DAS group had greater vowel errors followed by those with ELD, autism and PD in the sAOS group. While the scores ranged from 44% to 90% for DAS, in sAOS group, the scores ranged from 38% to 93% for those with autism, 50% to 93% for ELD group and 75% to 93% for those with PD. As seen from the scores, all the groups have attained a maximum of more than 90%. On careful examination, it was observed that only one participant in each of these groups showed scores nearing 90%. Hence it is evident that sAOS groups also exhibited vowel errors similar to participants with DAS, suggesting the co-occurrence of verbal praxis deficits in sAOS groups.

It is also notable that PVC scores were better compared to PCC scores. This could be attributed to the ease of production and smooth transition of articulators for vowels compared to consonants. However, participants with DAS exhibited greater vowel errors compared to sAOS group. Although there is variability with in these groups that is evident from the standard deviation values, there was no significant difference in their responses. The variability could probably be attributed to different levels of severity with in the groups. When rated for severity levels, it was found that DAS group showed a severity level of moderate to severe, while the groups with sAOS showed a severity of mild to moderate.

PCC and PVC scores in sentence level have not been extensively reported in DAS unlike for conversation. Based on the PCC and PVC scores for sentences, it can be inferred that all the groups showed similar responses, exhibiting greater consonant and vowel errors. The severity ranged from moderate to severe level for DAS group in PCC and PVC, while the severity for sAOS group ranged from mild to moderate level for PVC and moderate to severe level for PCC except for PD showing mild to moderate severity. The similarity in scores observed across groups with DAS and sAOS is indicative of co-occurring praxis deficit in the groups with sAOS.

c) Sequence maintenance score:

Sequencing difficulty is reported as a characteristic feature of developmental apraxia of speech (Forrest, & Morrisette, 1999; Whitebread, Dvorak, & Jakielski, 1999; Hall, 2000a; ASHA, 2002). Sequencing difficulties indicate the presence of deficits in coordinating and planning the utterances in a word or between words adequately, serving as an essential indicator of verbal praxis deficits. Sequence maintenance score for sentences were calculated using a three point rating scale (0 to 2, 0 indicating poor scores). Scoring was based on the number of words that were imitated in correct sequence by the participants. The raw scores were subjected to statistical analysis using one-way ANOVA. Results from table 37 shows significant difference between the groups at .001 levels of significance. Figure 24 depict the means, SDs and F values for sequence maintenance score at sentence level for all groups. For a total score of 20, the raw scores ranged from 5 to 12 for participants with DAS. However, participants with ELD, PD and autism also showed sequencing errors in sentences, with scores ranging from 7 to 15 for a total score of 20.

Table 37: Mean and SDs of sequence maintenance score for sentences.

Verbal praxis assessment-sentence level	Groups	Mean	SD	F(3, 27)
Sequence maintenance score	DAS	5.17	2.12	12.177***
	ELD	12.67	1.37	
	PD	11.17	1.60	
	Autism	10.29	2.43	

***- p<0.001

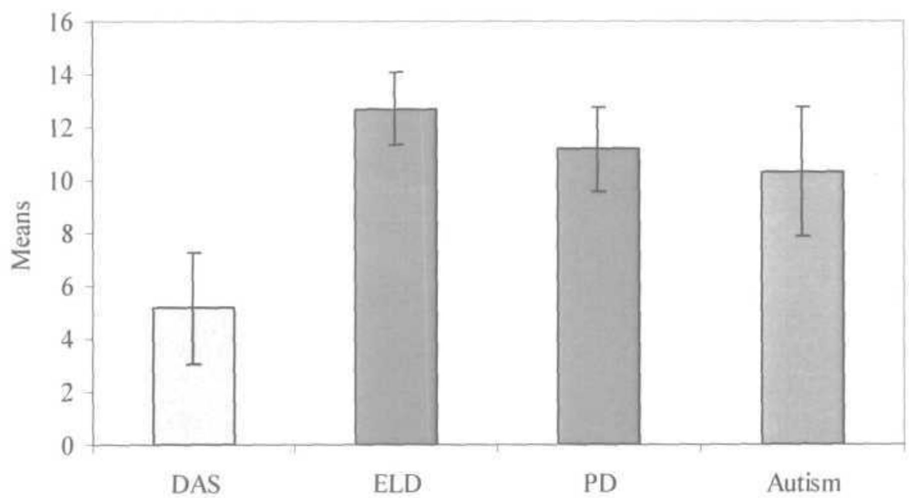

Figure 24: Means and SDs for sequence maintenance score at sentence level.

Duncan's post hoc analysis revealed significant difference between group with DAS and sAOS groups. There was no significant difference between groups with ELD, PD and autism. DAS obtained very poor sequence maintenance scores when compared to those with sAOS. The praxis deficits in sAOS groups is supported by another feature exhibited by these children in terms of increase in errors with increasing complexity (Stackhouse, 1992; Robin, 1992; Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Thoonen et al., 1997; Forrest & Morrisette, 1999; Lewis et al., 2004). hi order to investigate for decrease in sequence maintenance scores as a function of increasing length of sentences, number of participants who scored less than 2 were calculated for each sentence. The percentage of participants exhibiting errors per group was then computed as follows:

$$\frac{\textit{Numbers of persons with a score of less than 2}}{\textit{Total numbers of persons in the group}} \times 100$$

Percentage of participants exhibiting errors for sentences with syllable lengths ranging from 3 to 12 is depicted in figure 25 and table 38. The results reveals an increase in frequency of errors with increase in sentence length for groups with DAS and sAOS as well. However, number of participants exhibiting errors on the ten sentences were more in the DAS group when compared to those in sAOS groups. Both groups with DAS and sAOS showed a similar trend in terms of increase in percentage of participants exhibiting errors with increase in number of syllables in sentences as evident from Table 38. 100% of participants with DAS showed increased errors right from sentences with five syllables,In sAOS group, while 100% of ELD group showed errors from six syllables onwards, 100% of PD and autistics exhibited errors from seven syllables onwards. Hence both groups with DAS and sAOS seem to demonstrate increased errors which are again indicative of co-occurring verbal praxis deficit in sAOS groups.

Table 38: Percentage of participants with DAS and sAOS exhibiting errors in sentences of differing lengths.

SNo.	Sentence length	Percentage of participants affected			
		DAS	ELD	PD	Autism
1.	Three syllables	41.66	33.33	16.66	0
2.	Four syllables	66.66	50.00	33.33	28.57
3.	Five syllables	100	83.33	66.66	57.41
4.	Six syllables	100	100	83.33	85.71
5.	Seven syllables	100	100	100	100
6.	Eight syllables	100	100	100	100
7.	Nine syllables	100	100	100	100
8.	Ten syllables	100	100	100	100
9.	Eleven syllables	100	100	100	100
10.	Twelve syllables	100	100	100	100

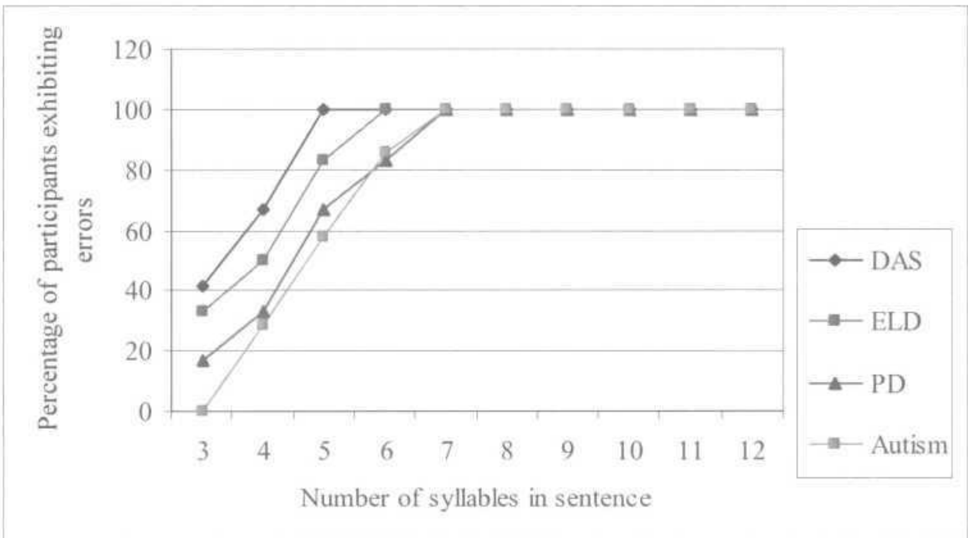

Figure 25: Sequence maintenance score in sentences.

In sentence level praxis assessment, the similarity in findings across the groups with DAS and sAOS are suggestive of praxis deficits in sAOS groups. PCC and PVC scores were similar indicating the presence of greater consonant and vowel errors in groups with DAS and sAOS. In terms of sequence maintenance scores, DAS group showed significantly greater sequencing errors when compared to sAOS groups. However, sAOS groups (ELD, PD and autism) also showed sequencing errors similar to DAS group but relatively lesser than those with DAS. The characteristic feature of DAS that is, increase in errors with increase in complexity was also evidently seen in participants with sAOS following a similar trend as participants with DAS. Thus difficulty in maintaining the sequence in sentences reflected in terms of increased errors with increase in sentence length in sAOS groups similar to those with DAS serve as definite indicators of co-occurring verbal praxis deficits in participants with sAOS.

£) Assessment of spontaneous speech

An attempt was made to record at least hundred utterances from spontaneous speech sample from each child by indulging in general conversation regarding his/her daily activities, home and school. Age appropriate pictures and other stimuli were used in order to obtain the sample that was then transcribed for subsequent analysis. However, speech samples of children with DAS and sAOS ranged from a minimum 25 words to a maximum 100 words. Hence, the medial 25 words were chosen for analysis. The speech samples of the participants were transcribed to identify the various error types. Each child's sample was analyzed separately and scored. Transcription was carried out using broad IPA transcription method. Analyses were carried out by calculating Percentage of Consonants Correct (PCC), Percentage of Vowels Correct (PVC) measures, groping, disfluencies and phonotactic analyses. The results are presented in the following sections:

1. Percentage of consonants and vowels correct (PCC and PVC)
2. Presence of disfluencies and groping errors
3. Phonotactic analysis

1) PCC and PVC:

All speech samples were transcribed using the broad system of IPA transcription. The transcribed samples were analyzed for percentage of correct consonants and vowels as done for sentences to arrive at the PCC and PVC scores. The scores when subjected to statistical analysis using one-way ANOVA, showed significant difference between the groups. The means, SDs and F values of the PCC and PVC scores are depicted in table 39.

Table 39: Means, SDs and F values of PCC and PVC scores for spontaneous speech samples.

PCC and PVC in spontaneous speech	Groups	Mean	SD	F(3, 27)	Severity
Percentage of consonants correct	DAS	63.88	12.24	2.207*	Mod - Sev
	ELD	78.25	4.30		Mild -Mod
	PD	72.63	8.31		Mild -Mod
	Autism	70.84	16.34		Mild -Mod
Percentage of vowels correct	DAS	70.87	4.14	4.798**	Mild -Mod
	ELD	85.29	2.51		Mild -Mod
	PD	81.73	2.92		Mild -Mod
	Autism	79.24	3.82		Mild -Mod

'-p<0.05;-p<0.01**

Duncan's post hoc comparison revealed significant difference between groups with DAS and ELD in both PCC and PVC. There is no significant difference between participants with DAS, PD and Autism in both these parameters suggesting similar performance in groups with PD and Autism as seen in DAS group. The percent consonant correct and percent vowel correct for conversation was found to be least in participants with DAS than in ELD. Hence it is suggestive of more consonant and vowel errors in participants with DAS than that seen in participants with ELD.

The PCC scores ranged from 40% to 84% in DAS and in sAOS groups, the PCC scores ranged from 65% to 91% for ELD, 54% to 90% for PD and 50 to 90% for autism. While there were only two children (33%) from ELD and PD , there was only one child (14%) with autism showing 90% scores in the sAOS group. None of the children attained a score of above 90% in DAS group. Lower PCC scores are reported for children with DAS (Thoonen, Maassen, Gabreels, & Schreuder, 1994; Shriberg, Aram, & Kwaitkowski, 1997b, 1997c; Velleman, & Shriberg, 1999; Shriberg & McSweeny, 2002). PCC scores are often recommended as a clinical procedure in the Speech Disorders Classification System (Shriberg, 1993) in arriving at a diagnosis of CAS. While PCC scores are often used to diagnose the severity of the problem, Lowe (1984) has considered using these scores as a measure of progress in therapy.

PVC scores ranged from 50% to 89% for DAS. In sAOS group, the scores ranged from 74% to 95% for ELD, 73% to 90% for PD and 68% to 90% for autism. Here again, the 90% scores were attained by only two children in ELD (33%), PD (33%) and autism

(28%) groups. None of the participants with DAS scored above 90%. According to the severity scale, the severity was evaluated for each group of participants with DAS, ELD, PD and Autism. In PCC, DAS was rated as moderate to severe whereas all the groups in sAOS were rated as mild to moderate. On the other hand, PVC scores were rated as mild to moderate for groups with DAS as well as sAOS. There is variability observed with in these groups showing the attribute of heterogeneity among these participants. Lower PVC scores for conversation are reported for children with developmental apraxia of speech by many investigators (Shriberg, Aram, & Kwiatkowski, 1997b, 1997c; Shriberg & McSweeny, 2002; Davis, Jacks, & Marquardt, 2005).

A difference was noticed in terms of PCC and PVC scores for sentences and conversation for the participants with DAS and sAOS. In sentences the participants were involved in imitation task where as conversation involved elicitation task. It was seen that the severity ratings for PCC and PVC did not differ significantly in the imitation task for sentences. However, there was a significant difference between DAS and ELD in the PCC and PVC scores for conversation. Thus elicitation task probably is more sensitive and effective in assessing actual errors of the participants and in differentiating the performance of groups.

Both PCC and PVC scores serve as a diagnostic measure for developmental apraxia of speech. Although children with DAS are reported to have more of vowel errors and consonant substitutions, the findings of this study are observed to have greater PVC scores compared to PCC. This is an evidence to support the presence of similarity in terms of more consonant errors than vowel errors in children with DAS and sAOS. These

Articulation difficulties and dysfluencies are viewed as resultant of developmental apraxia (Yoss and Darley, 1974) with underlying speech motor control dysfunction (Kent, 2000). Children with phonological disorders are also presumed to show features of developmental apraxia (Byrd & Co6per, 1989; St Louis et al, 1991; Conture et al., 1993; Wolk et al., 1993; Bernstein Ratner, 1995; Paden and Yairi, 1996; Yaruss & Conture, 1996; Shriberg, Aram & Kwiatkowski, 1997a; Ratner, 1998; McCabe, Rosenthal & McLeod, 1998; Louko et al., 1999; Melnick & Conture, 2000).

Besides groping and dysfluencies, distortion errors have been reported in children with DAS and is considered as a diagnostic feature of DAS (Williams, Ingham, & Rosenthal, 1981; Shriberg, Aram & Kwiatkowski, 1997a, 1997b; Strand, 2003). Children with apraxia are reported to produce mostly distortions or substituted distortions (Robin, 2002). It is considered as a predominant error type subsequent to substitutions (Itoh & Sasanuma, 1984; Thoonen et al, 1997). Distortions are considered as speech symptoms resulting from deficits in motor-planning. These distortion errors were observed in sAOS group too.

Groping, dysfluencies, and distortion errors definitely seem to serve as effective indicators of co-occurring verbal praxis deficit in participants with sAOS, viz, ELD, PD and autism. Among these groups, autism group demonstrated more of praxis deficits compared to PD and ELD. However, based on the findings from various sections in verbal praxis skills assessment, which shows variability among participants, it can be inferred that all the groups with sAOS exhibit verbal praxis deficit with varying degrees of severity and there are varying percentages of participants in each group. This is because not all the children in each group with sAOS showed these errors. The percentage of individuals with ELD, PD and autism who exhibit verbal praxis deficits supports the presence of praxis deficit in these groups.

3) Phonotactic Analysis

Phonotactics refers to the way syllables behave in utterances resulting in errors affecting an entire syllable or word, in turn affecting the syllable structure in a word. Different languages have different phonotactic patterns but there is always a trade-off among the patterns that is allowed by the language (referred to as Phonotactic constraints). The critical significance of syllable-level and word-level analysis in child (and adult) phonologies in all languages is increasingly documented over the past decades (Ferguson & Farwell, 1975; Ferguson, 1978; Macken, 1979). Velleman (1998) presumes that DAS appears to differ from other phonological disorders and delays and is more specifically a phonotactic disorder. Hence, phonotactic analysis of speech samples of all the participants with DAS and sAOS were carried out. This analysis would serve to investigate the various syllable structures and patterns used during speech production especially in a discourse.

The following formula was given by Velleman (1998) to calculate the frequency of occurrence of different syllable shapes, word shapes and cluster variants in the speech samples of children.

$$\frac{\text{Number of CVsyllables}}{\text{Total number of syllables}} \times 100 = \% \text{ CVsyllables}$$

$$\frac{\text{Number of initial clusters}}{\text{Total number of words}} \times 100 = \% \text{ initial clusters}$$

$$\frac{\text{Number of disyllabic words}}{\text{Total number of words}} \times 100 = \% \text{ disyllabic words}$$

Similar formulae were used to calculate the percentage occurrence of other syllable shapes (V, VC, CVC, CCV), word shapes (mono, tri and multisyllabic words) and different cluster patterns (Refer Appendix II). The results are presented in the following sections:

/) *Syllable Shapes*

The speech samples were analyzed and following syllable shapes were observed: CV, CCV, CVC, V, and VC. The mean percentage of syllable shapes were calculated in order to categorize them based on the frequency of occurrence of each type of syllable shape. The scale suggested by Velleman (1998) was used to categorize the frequencies. The approximate frequencies are:

- Predominant: 61-100%
- Frequent: 41-60%
- Occasional: 16-40%
- Rare: 1-15%
- Absent: 0%

The raw scores obtained based on the phonotactic analysis were converted to percentage scores and was subjected to statistical analysis using 'One-way ANOVA'. This was employed to check for significant differences between the groups with DAS, ELD, PD and Autism. The mean and SD are tabulated in table 41.

Table 41: Mean Percentage, SD and frequency of occurrence of syllable shapes for DAS and sAOS groups.

Syllable shape	Groups	Mean	SD	F (3, 27)	Frequency
CV	DAS	69.82	13.08	1.424	Predominant
	ELD	64.96	3.44		Predominant
	PD	68.50	4.71		Predominant
	Autism	57.25	14.34		Frequent
CCV	DAS	14.80	4.18	0.260	Rare
	ELD	12.85	2.07		Rare
	PD	11.02	3.06		Rare
	Autism	12.59	5.65		Rare
CVC	DAS	2.27	1.55	15.471***	Rare
	ELD	6.53	1.52		Rare
	PD	8.09	1.27		Rare
	Autism	4.83	2.78		Rare
V	DAS	10.34	2.95	6.728***	Rare
	ELD	7.27	2.16		Rare
	PD	7.55	2.43		Rare
	Autism	5.13	1.89		Rare
VC	DAS	1.53	1.35	0.287	Rare
	ELD	1.63	0.57		Rare
	PD	1.76	0.55		Rare
	Autism	1.82	0.83		Rare

***-P<.001

From Table 41, it is clear that 'CV syllable shapes are the most predominantly used syllable shapes by groups with DAS and ELD & PD with sAOS. On the other hand, it is frequently used by participants with autism, when compared to other syllable shapes.

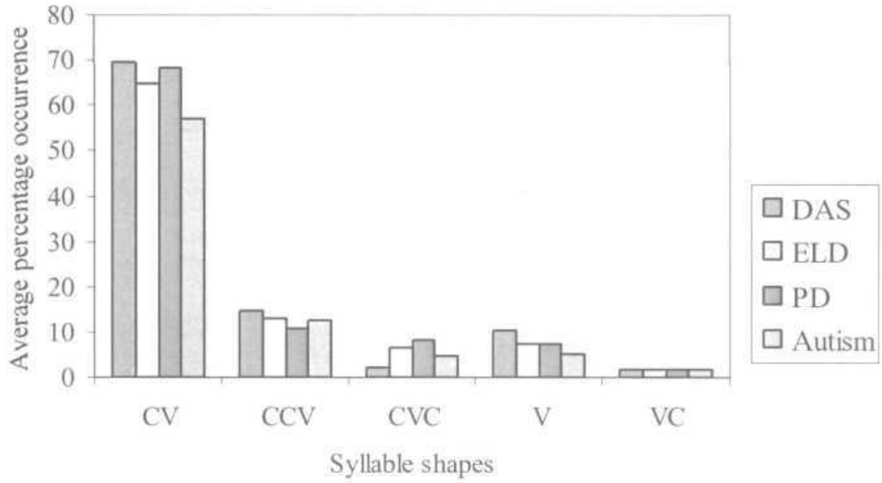

Figure 26: Syllable shapes across children with DAS and sAOS groups

Figure 26 reveals similar trend in the frequency of occurrence of syllable shapes for the groups with DAS and ELD and autism with sAOS. PD also exhibited similar trend as that of DAS varying only in tenns of frequent use of the syllable shape CVC followed by V unlike ELD and autism that showed more frequent use of Vs followed by CVC. Of all the syllable shapes, from table 41 and figure 26 it is evident that CV syllables are frequently used by participants with DAS and sAOS groups followed by the use of CCV.

Duncan's post-hoc test revealed significant difference between the groups, viz, group I (DAS) and group II (Suspected Apraxic Group), only in terms of the syllable shape CVC and V. It did not reveal significant difference between groups with ELD, PD and autism for any of these syllable shapes. The syllable shape CVC is maximally used by participants with Autism followed by developmental apraxics, which in turn is followed by participants with PD and ELD as shown by the mean percentages. DAS group had the least score suggesting minimal usage of CVCs than the suspected apraxic group which shows frequent usage of CVCs although they were native speakers of Kannada which demands open syllables with vowel ending.

It is also seen that the syllable shape, V is predominantly used by the participants with DAS and minimally used by participants in Group II with sAOS. Although participants in both the groups had bilingual exposure the DAS group preferred using only open syllables ending with vowels and not the closed syllables. But it should be noted that the open syllable CV did not show significant difference between the groups. The frequency of occurrence of CV is seen to be maximum compared to other syllable shapes in both DAS and sAOS. CV syllables are reported to be acquired earlier by Kannada speaking children and so they are produced frequently than other syllable shapes in Kannada [Deputy, 1984 (in English); Rupela & Manjula, 2006 (in Kannada)]. This suggests the preference for monosyllable usage, which is similar across the two groups with DAS and sAOS.

The syllable shape CCV and V were found to occur frequently in participants with DAS and sAOS. The occurrence of CCV could be due to over stressing of syllables resulting in gemination of singleton consonants and non-geminate clusters. The increased use of V syllables could be due to consonant deletions in different positions, predominantly in the initial position and simplified production of adult target words. Other syllable shapes did not show any significant difference between the groups. This shows that the performance scores of the participants in the two groups are similar. This finding again points to similar frequency of occurrence of syllable shapes in participants with DAS and sAOS, suggestive of co-occurrence of DAS in sAOS groups.

2) Word Shapes

The speech samples of participants from both groups were analyzed for following word shapes: Mono syllables, Bisyllables, Trisyllables, Four syllables, and Five syllables. The maximum length of utterance used by participants in the groups included 5 syllables. This was carried out to find out and analyze the word shapes which were predominantly used by the participants in group I and group II. The results were statistically analyzed and are tabulated in Table 42. Figure 27 indicates the frequency of usage of various word shapes in DAS and sAOS groups.

Table 42: Means, SDs and one-way ANOVA for word shapes in groups with DAS and sAOS.

Word shape	Groups	Mean	SD	F (3, 27)	Frequency
Mono syllables	DAS	2.46	1.13	0.787	Rare
	ELD	1.83	1.29		Rare
	PD	1.67	1.89		Absent
	Autism	2.07	1.96		Rare
Bisyllables	DAS	68.37	11.08	4.523*	Frequent
	ELD	51.91	2.88		Frequent
	PD	55.83	3.02		Frequent
	Autism	58.57	8.19		Frequent
Trisyllables	DAS	32.50	7.53	1.875	Occasional
	ELD	40.41	5.34		Occasional
	PD	40.41	7.14		Occasional
	Autism	37.14	7.83		Occasional

Four syllables	DAS	14.83	7.41	1.441	Rare
	ELD	16.^6	3.41		Occasional
	LPD	22.08	7.65		Occasional
	Autism	20.71	3.45		Occasional
Five syllables	DAS	0.18	0.66	0.257	Rare
	ELD	1.36	1.04		Rare
	PD	1.26	1.09		Rare
	Autism	1.42	1.56		Rare

- $p<.05$

Among the various word shapes that were analyzed from the speech samples, Duncan's post hoc test revealed significant difference between the participants with DAS and sAOS in usage of bi-syllable words. Bisyllables were more frequently used by the DAS group when compared to those with ELD, PD and Autism. No significant differences were revealed between groups with ELD, PD and autism for bisyllables. There was no significant difference for other word shapes also between the two groups.

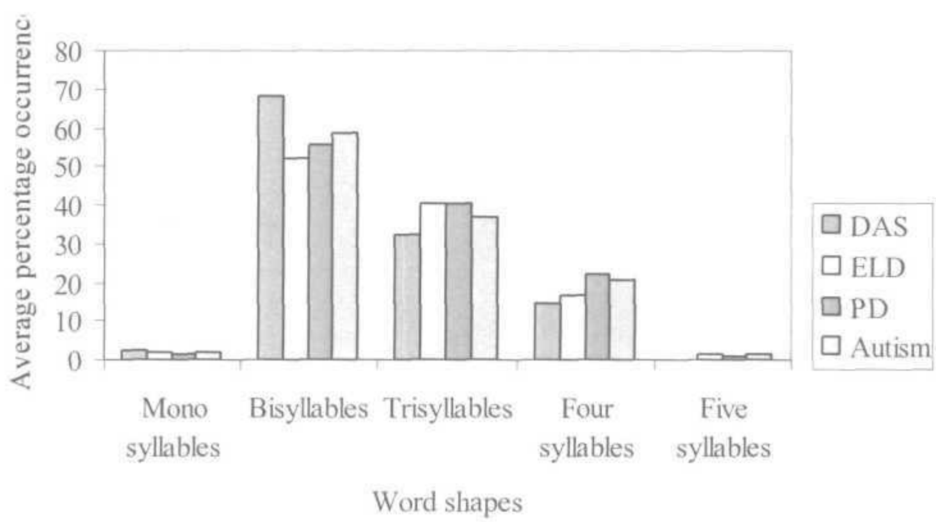

Figure 27: Comparison of word shapes across groups with DAS and sAOS

As is evident in Figure 27, increased use of bisyllables were observed in both groups with DAS and sAOS, followed by the use of tri-syllables and four syllables. Monosyllables were minimally used by both groups of participants. Rupela and Manjula (2006) have reported that monosyllables are rarely used and bisyllables are more frequently used by typically developing children speaking Kannada language. Findings in this study also show rare occurrence of monosyllables and frequent occurrence of bisyllables in groups with DAS and sAOS. The occurrence of monosyllables in children with DAS and sAOS could be attributed to the high degree of omissions such as syllable deletions in various positions. The frequency of use of trisyllabic and multi syllabic (four and five syllable words) words decreased as the syllable length increased. The maximum number of syllables used by the participants with DAS and sAOS were found to be five syllables, but this was very infrequent in DAS and sAOS groups compared to the lower order syllable lengths.

On rating the percentage and frequency of occurrence of the word shapes using the subjective scale given by Velleman (1998), it was evident that bisyllables were the most frequently used word shape used by participants with DAS as well as those with sAOS (ELD, PD and autism). Trisyllabic and multisyllabic words were less frequent. Velleman (1994) reported that individual children demonstrate preferred sounds, syllable shapes, or word shapes. Many children are said to have a preference for open ('CV') syllables. (Branigan, 1976; Grunwell, 1982; Ingram, 1989). Other preferences are preluded to include syllables that require a minimum of lingual movement with in the syllable (e.g., [di], in which the tongue tip remains in the alveolar vicinity through out).

Word shapes may be preferred based upon minimal oral-motor planning requirements. Reduplicated word, for instance, require the child to plan only one syllable, which is then repeated. Reduplication is well-documented in early child phonology (Branigan, 1976; Schwartz, Leonard, Wilcox and Folger, 1980; Fee and Ingram, 1982; Schwartz & Leonard, 1983; Ferguson, 1983; Lleo, 1990). Other children are reported to show preferences that are based on the order of consonantal places of articulation (e.g., labial consonant before velar consonant) or of vowels (low vowel before high) (Velleman, 1994). Findings of this study with respect to preferences for syllable shapes and word shapes supports the earlier studies in literature.

3) Cluster patterns

The various clusters that were observed in the speech samples of groups with DAS and sAOS were the onset clusters (word initial clusters CC-, e.g., svatja, meaning clean), medial clusters (geminated clusters, -CC-g, e.g., tatte, meaning plate, and non-geminated, -CC-ng, e.g., bartida:re meaning they are coming) and final clusters (words borrowed from English, e.g., Jirt). Mean, SD and one-way ANOVA values are depicted in Table 43. Figure 28 illustrates the percentage occurrence of different clusters for two groups of participants. Of the cluster types evaluated, Duncan's post hoc test revealed a significant difference in the occurrence of medial geminated consonant clusters between groups I and II.

Table 43: Mean and SD of Frequency of occurrence of Consonant Clusters in Group I and II.

Clusters patterns	Groups	Mean	SD	F (3, 27)
Initial clusters	DAS	1.17	1.47	1.482
	ELD	1.17	1.17	
	PD	2.83	2.71	
	Autism	2.14	1.77	
Medial geminated clusters	DAS	26.66	9.06	2.831*
	ELD	36.25	1.36	
	PD	33.33	10.20	
	Autism	33.92	10.08	
Medial non-geminated clusters	DAS	12.91	8.77	1.112
	ELD	15.33	2.58	
	PD	19.25	4.10	
	Autism	18.57	10.69	
Final clusters	DAS	0.67	0.13	0.772
	ELD	1.50	0.55	
	PD	1.33	1.28	
	Autism	1.43	1.35	

- $p<.05$

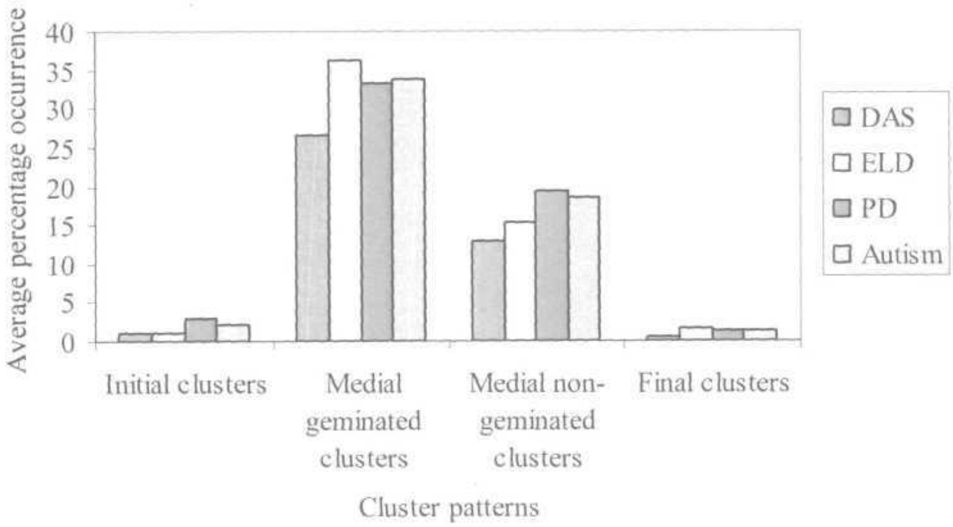

Figure 28: Comparison of cluster patterns across groups with DAS and sAOS

Medial geminated clusters were less used by participants with DAS than that used by participants with ELD, PD and Autism. This difference could be attributed to the simplifications which were seen more frequently in the speech of participants with DAS. Also, initial and final CCs were produced rarely in participants with DAS as well as those in suspected apraxic group. This is probably because initial clusters are reportedly acquired later by typically developing children compared to medial ones due to which there is a phonotactic constraint laid on the children (Rupela & Manjula, 2006).

Amongst the medial clusters, medial geminated (-CC-g) clusters were frequently used by both DAS and sAOS compared to the medial non-geminated clusters. Medial geminated clusters are reported to be acquired first by typically developing children (Rupela & Manjula, 2006) and hence the greater usage of these by participants with DAS and sAOS. Shriberg et al., (2001) reported destressing of stressed syllables and stressing of stressed syllables in their study. Support can be drawn fro the observations of Shriberg et al. (2001) in hypothesizing that probably increased stressing resulted in the production of geminate clusters. ELD group showed higher percentage medial geminated clusters followed by those with autism and PD. DAS showed minimal usage of these clusters and hence it may be stated that they resorted to use of simple phonotactic patterns. Both DAS and sAOS groups showed very few occurrences of final clusters, which were not significant.

The significance of syllable-level and word-level analysis for describing child phonologies in all languages has been increasingly recognized over the past decades (Ferguson & Farwell, 1975; Ferguson, 1978; Macken, 1979). Phonotactic analysis gives an overview as to how sounds are being used by children in various contexts in a continuous discourse.

The commonly reported phonotactic constraints observed in young children with DAS include limitations and gaps in the sound repertoire (both consonant and vowel), with the possibility that the child may acquire some later developing sounds while missing earlier developing sounds. DAS children may demonstrate very limited use of syllables, possible use of an extended single sound or few vocalizations at all. The children may have difficulty combining the sounds that they have in the repertoire with limited variation of vowels and reduced syllable shape inventory (Davis & Velleman, 2000; Strand, 2003; Smit, 2004). This could be attributed to the difficulty in achieving and maintaining articulatory configurations.

Other potential phonotactic deficits serving as diagnostic characteristics of apraxia in young children include: limited consonant and vowel repertoire, higher degree of omissions, sequencing difficulties with phonemes and syllables; increased errors with increased length of utterance as in multi syllabic words and inconsistency in articulation (Murdoch, Porter, Younger & Ozanne, 1984; Stackhouse, 1992; Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Forrest, & Morrisette, 1999; Hall, 2000a; ASHA, 2002; Marquardt, Sussman, Snow & Jacks, 2002; Strand, 2003). While a few investigators hypothesized that the underlying deficit is the syllabic framework (Marquardt, Sussman, Snow, & Jacks, 2002; Maassen, 2002; Nijland, Maassen, van der Meulen, Gabreels, Kraaimaat, & Schreuder, 2003), the viewpoint of other researchers (Crary, 1993; Hall, Jordan & Robin, 1993; Lewis et al. 2004) suggests that DAS may be attributed to deficits in the child's ability to organize and sequence speech components (e.g., speech sounds, syllables, speech melody). The phonotactic constraints observed in DAS as well as sAOS groups serve as supportive indicators of co-occurring verbal praxis deficit in sAOS groups

Studies on segmental errors apart, profiles on use of prosody has also been documented. Inappropriate stress patterns in children with DAS (Shriberg, Aram and Kwiatkowski, 1997) is well reported. It was found that children with DAS made less distinction between prosodic features such as stressed and unstressed segments when compared to typically developing children. Odell and Shriberg (2001) found that inappropriate stress in some children with suspected AOS is consistent with both representational and speech motor control processing issues. Shriberg et al., (2001) observed that DAS children distressed the stressed syllables and / or overstressed the stressed syllables giving an impression of a possible representational deficit (destressing), and a speech motor processing deficit (overstressing). The source of the inconsistent realization of lexical stress by at least some speakers with suspected Apraxia of Speech (sAOS) is proposed to be consistent with the construct of an inherited praxis disorder in speech motor control (Shriberg et al., 2003).

Autistic children are reported to produce high percentages of atypical vocalizations (Wetherby, Yonclas & Bryan 1989; Amoroso 1992; Sheinkopf et al. 2000), deficits in syllable production (Wetherby, Yonclas & Bryan 1989; Amoroso 1992; Sheinkopf et al. 2000), unusual patterns of phonological development (Bartolucci, Pierce, Streiner & Eppel, 1976; Wolk & Edwards, 1993; Velleman, 1996; Wolk & Giesen, 2000), restricted use of phonological contrasts necessary to signal meaning differences (Wolk & Edwards 1993; Foreman 2001), and high levels of variability (Velleman, 1996). Reported atypicalities in phonological development include deviant phonological processes and unexpected phonetic repertoires (Wolk & Edwards, 1993; Wolk & Giesen, 2000) as well as developmental asynchronies. High-functioning autism (HFA) and Asperger's syndrome are also reported to demonstrate a higher incidence of persistent articulation errors, prosodic differences (Shriberg et al. 2001), and more general motor deficits than control participants (Noterdaeme, Mildenberger, Minow, & Amorosa, 2002). Findings of this study also show the existence of such atypical features in autistics.

Empirical investigations that support motor-related deficits have failed to systematically differentiate communication deficits underlying autism that are primarily non-verbal oral motor, motor speech-related, moto-linguistic, or phonological in nature. Furthermore, findings are contradictory with respect to syllable production (Wetherby et al. 1989; Amoroso, 1992; Sheinkopf et al. 2000) and articulation errors (Bartolucci et al. 1976; Bartolucci & Pierce 1977). Rapin (1996) studied oromotor skills and phonology in the autistics and concluded that clusters exist with these children. Generalization from this study is not possible as the study did not selectively differentiate non-verbal oral apraxia, apraxia of speech, dysarthria, and phonological deficits in the participants. There are no such studies reported in children with PD and ELD. Therefore, tasks with increasing complexity as used in this study are crucial in understanding the phonotactic constraints which serves as potential diagnostic markers for DAS. Phonotactic difficulties indicative of praxis deficits were also observed in children with sAOS, supporting the presence of such phonotactic constraints in children with autism, PD and ELD, in turn substantiating the existence of praxis deficits in these children.

Analysis of spontaneous speech revealed that participants with sAOS exhibited considerable praxis deficits. PCC and PVC scores were poorer in participants with DAS. They did not differ significantly from groups with PD and autism. ELD group differed significantly from those with DAS on PCC scores. DAS group exhibited greater number of consonant and vowel errors. Yet, the sAOS groups showed similar PCC and PVC scores indicating the presence of consonant and vowel errors as that of the DAS group. Disfluencies and groping errors in spontaneous speech also suggested considerable deficits in verbal praxis skills. Groping was significantly greater in participants with DAS when compared to sAOS groups. Disfluencies were similar across the two groups. Phonotactic constraints and trends were revealed on the analysis of different syllable, word and cluster shapes. Phonotactic analyses revealed that syllable shapes characteristically seen in DAS also existed in children with sAOS in terms of decreased use of complex cluster patterns such as initial clusters, medial non-geminated clusters, CVC and VC syllables and multisyllabic words. Participants with sAOS also tended to use simpler phonotactic patterns like medial geminated clusters, CV syllables and fewer clusters similar to participants with DAS, suggesting the presence of co-occurring verbal praxis deficits in individuals with sAOS.

DAS is described by Velleman (1994) as a cluster existing among children with moderate to severe phonological disorders, characterized by slow, labored speech. Those who are severely affected are reported to produce very simple open CV syllables with which many children begin the acquisition of words. They may be unable to move beyond this level. But there is disagreement about whether such children form a distinct etiologic cluster (Deputy, 1984). According to Hodge (1994), "delays in speech onset associated with CAS are typically associated with expressive language delays and may be part of a more global language processing delay that put these children at risk for language-based social and academic problems (e.g. reading, spelling, writing)". Some researchers propose that deficits in both the motor programming and the linguistic domains underlie DAS (Aram & Nation, 1982; Edwards, 1984). Specifically, children with DAS may have deficits in phonological representation, as demonstrated by their inability to rhyme (Marion, Sussman, & Marquardt, 1993) and to identify syllables (Marquardt, Sussman, Snow, & Jacks, 2002).

To support the notion that there is involvement of phonological encoding in DAS, possible effects of syllable structure on patterns of consonant production were investigated by Thoonen et al (1997). It was observed that syllabic structure of words played an important role during phonological encoding in both normal and disordered speakers (Shattuck-Hufnagel, 1985). The frequencies of singleton and consonant error types in DAS were reported to be highly dependent on the positions of the consonant or cluster with in the syllable. Consonant omissions and cluster reductions occurred more frequently in syllable-final position, where as consonant substitutions were predominant in syllable initial position, in this study, initial consonant deletions were observed more frequently in all the groups. Cluster reductions were common across various positions in the word.

There are several characteristics of apraxic speech that support an interpretation in which syllable context plays a predominant role in speech production. Deficits in timing and co-ordination are examples that have been reported in voice-onset-time studies (Kent and Rosenbek, 1983; Ziegler and Von Cramon, 1986a); and delayed transitions and problems in phasing the articulatory movements in apraxia of speech (Ziegler & von Cramon, 1985; Ziegler & von Cramon, 1986b; Whiteside & Varley, 1998). These types of errors are more often described in terms of articulatory syllabic context influences, than in terms of phoneme selection and sequencing. Furthermore, results of Marquardt, Sussman, Snow and Jacks (2002) suggested a breakdown in the ability of children with DAS to perceive 'syllableness' and to access and compare syllable presentations with regard to position and structure. Likewise, syllabic context plays a role in the planning and programming of speech that is in transition from a phonologic representation to the motor program (Levelt, 1989; Ozanne, 1995). Nijmegan et al., (2003) report of deficit in planning of syllables in speech production in children with DAS. Since syllable level errors were evident in sAOS group, they also seem to show errors in planning of syllables.

Phonological development in DAS is usually described as atypical, and deviant. Although some typical phonological patterns can be identified, each child's phonological response to his or her oral-motor limitations is reported to be idiosyncratic. Hence a child's entire phonological system has to be treated including linguistic patterns as well as motoric limitations (Nijland et al., 2002). A typical phonological development, or a phonological system characteristic for DAS, has not been found (Shriberg et al., 1997).

A few studies discuss the presence of praxis deficits in children with autism, expressive language impairment and phonological impairment. Velleman and Strand (1994) claimed that a focus on the syllable is crucial to understand the phonological disorder which is part of the symptom complex of DAS. Velleman (1994) illustrated the crucial role of the syllable in understanding the phonological systems of young children with DAS. The interaction among oral-motor skills, phonetics, phonology, learning style, and even syntax with in their developmental linguistic systems were elucidated.

The finding of this study with respect to praxis deficit in autistics supports the findings of earlier studies (Rogers & Pennington, 1991; Velleman, 1996; Page & Boucher, 1998; Sheinkopf et al. 2000; Wolk & Giesen 2000; Kjelgaard & Tager-Flusberg 2001; Shriberg et al., 2001; Mostofsky et al., 2006). One of the most consistent motor findings associated with autism is deficient performance of skilled motor gestures (DeMyer et al., 1981; Jones & Prior, 1985; Ohta, 1987; Smith & Bryson, 1994; Rogers et al., 1996). Mostofsky et al. (2006) report a generalized praxis deficit in children with high functioning autistics by assessing the limb praxis using tasks of imitation, command and tool use. Earlier studies in literature also reported on limb praxis deficits and suggested that a dyspraxic deficit is associated with autism (DeMyer et al., 1972, 1981; Jones & Prior, 1985; Ohta, 1987; Rogers et al., 1996). Mostofsky et al. (2006) implies their findings to reflect abnormalities in higher circuits which are important for acquisition of sensory representations of movement and / or motor sequence programs necessary to execute them. But studies on verbal dyspraxia in autistics are only a few in number (Boucher 1976; Bartolucci & Pierce 1977; Wetherby, Yonclas & Bryan 1989; Amoroso 1992; Wolk & Edwards 1993; Velleman, 1996; Page & Boucher, 1998; Sheinkopf et al.

2000; Kjelgaard & Tager-Flusberg 2001; Shriberg et al. 2001). Moreover, the reported studies do not address specific issues in praxis deficit viz, oral motor, oral praxis and verbal praxis, in the same group of participants. This study found that participants with autism exhibited praxis deficits in skills, oral motor, oral praxis, verbal praxis, similar to participants with DAS, although the severity probably was mild.

The presence of praxis deficit in children with phonological disorder and Expressive Language disorder also supports the earlier studies (Prizant, Audet, Burke, Hummel, Maher & Theadore, 1990; Kent, 1992; Rogers-Adkinson & Griffith, 1998). These children are frequently observed to produce unintelligible responses, which result in frequent interactional breakdowns. Because the characteristics of the co-occurring disorders may conflict with the characteristics of DAS, it may be harder to identify DAS in a given individual.

Aram and Nation (1982) posited that multiple components of expressive grammar were involved in the disorder and thus advocated the term 'Developmental Verbal Apraxia' instead of 'Developmental Apraxia of Speech', to include the linguistic aspects of the disorder. They emphasized that "...articulatory and language disorders do not simply coexist, but that both stem from a common breakdown in the selection and sequencing of both language and articulatory elements". They observed that children with apraxic difficulties used disordered lexical and syntactic formulation also. Hence, they believed that breakdown in speech programming underlie both language and articulation disorders that are seen to co exist in DAS. Similar observations were also made by Paul and Shriberg (1982), Panagos & Prelock (1984), and Love (1984). On par with the above views, the findings of this study have pointed to indicators for the presence of co-occurring verbal praxis deficits in children with autism, ELD and PD.

Summary:

In summary, an assessment protocol was used to assess oral motor, oral praxis and verbal praxis skills in participants with DAS and sAOS (ELD, PD and Autism). From the findings in general, participants with DAS showed poor performance across most of the tasks when compared to the sAOS groups but did not differ significantly from those with sAOS on majority of the tasks. Praxis skills assessment showed deficits even in the suspected apraxic group as seen in participants with DAS with varying degree of severity as evident by hierarchical cluster analysis. The findings based on Cluster Analysis are summarized for the sections of oral motor, oral praxis and verbal praxis skills and the results are depicted in table 44 and figures 29a, 29b, 30a, 30b, 31a and 3 lb.

The hierarchical cluster analysis generated 3 clusters with each cluster depicting varying percentage of participants with sAOS who performed similar to those with DAS indicating the presence of co-occurring features of DAS in groups with ELD, PD and autism. The score range of each cluster was determined by the SYSTAT software - version 12 depending upon the closest association of performance scores obtained by the participants with DAS and sAOS. Cluster I depicts those participants with severe oral and verbal praxis errors followed by those in cluster II with moderate praxis deficits and cluster III depicts participants who had mild difficulty or normal in performing the tasks. However, for the section on oral motor assessment, for oral structures at rest, cluster III suggested normal performance obtaining the maximum score of 16.

Table 44: Results of Oral motor, oral praxis and verbal praxis skills for DAS and sAOS groups on Cluster Analysis.

1. Oral Motor Assessment								
a) Oral structures at rest								
Clusters	DAS		ELD		Autism		PD	
	No.*	%**	No.*	%**	No.*	%**	No.*	%**
I	6	50.00	3	50.00	1	14.28	0	0
II	2	16.66	2	33.33	2	28.57	2	33.33
III	4	33.33	1	16.66	4	57.74	4	66.66
b) Function of oral mechanism for speech								
Clusters	DAS		ELD		Autism		PD	
	No.*	%**	No.*	%**	No.*	%**	No.*	%**
I	8	66.66	1	16.66	1	14.28	0	0
II	3	25.00	5	83.33	5	71.42	2	33.33
III	1	8.33	0	0	1	14.28	4	66.66
2. Oral Praxis Assessment								
a) Isolated Oral Movements								
Clusters	DAS		ELD		Autism		PD	
	No.*	%**	No.*	%**	No.*	%**	No.*	%**
I	3	25	0	0	3	42.85	1	16.66
II	6	50	1	16.66	3	42.85	2	33.33
III	3	25	5	83.33	1	14.28	3	50
b) Sequential Oral Movements								
Clusters	DAS		ELD		Autism		PD	
	No.*	%**	No.*	%**	No.*	%**	No.*	%**
I	9	75	0	0	2	28.57	0	0
II	3	25	2	33.33	4	57.74	3	50
III	0	0	4	66.66	1	14.28	3	50
3. Verbal Praxis Assessment								
a) Isolated Verbal Movements								
Clusters	DAS		ELD		Autism		PD	
	No.*	%**	No.*	%**	No.*	%**	No.*	%**
I	3	25.00	0	0	2	28.57	1	16.66
II	7	58.33	4	66.66	1	14.28	3	50.00
III	2	16.66	2	33.33	4	57.74	2	33.33
b) Sequential Verbal Movements								
Clusters	DAS		ELD		Autism		PD	
	No.*	%**	No.*	%**	No.*	%**	No.*	%**
I	8	66.66	0	0	3	42.85	0	0
II	4	33.33	2	33.33	2	28.57	2	33.33
III	0	0	4	66.66	2	28.57	4	66.66

* - Number of individuals; ** - Percentage of individuals

1. Oral Motor Assessment

a) Oral Structures at Rest

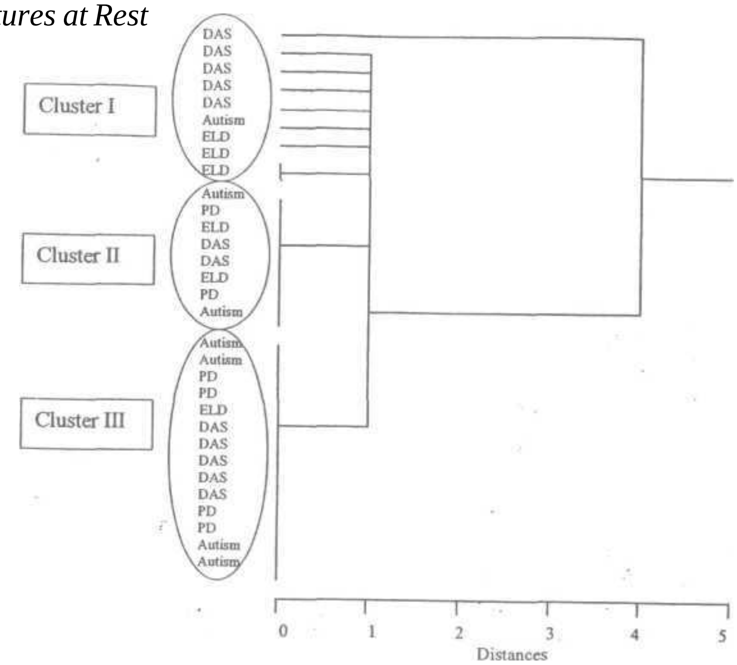

Figure 29a: Cluster tree depicting the clusters I, II and III for oral structures at rest.

b) Function of Oral mechanism for Speech

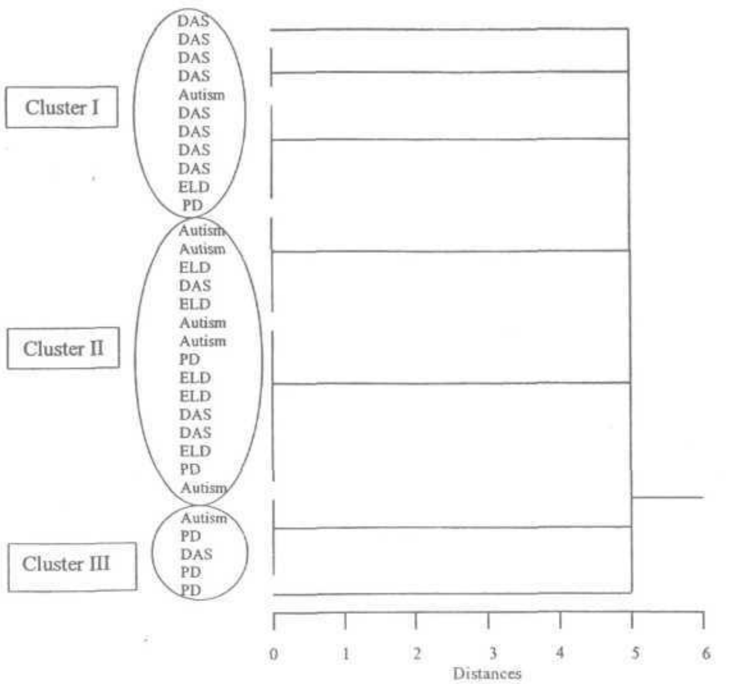

Figure 29b: Cluster tree depicting the Clusters I, II and III for assessment of function of oral structures.

2. Oral Praxis Assessment

a) Isolated Oral Movements

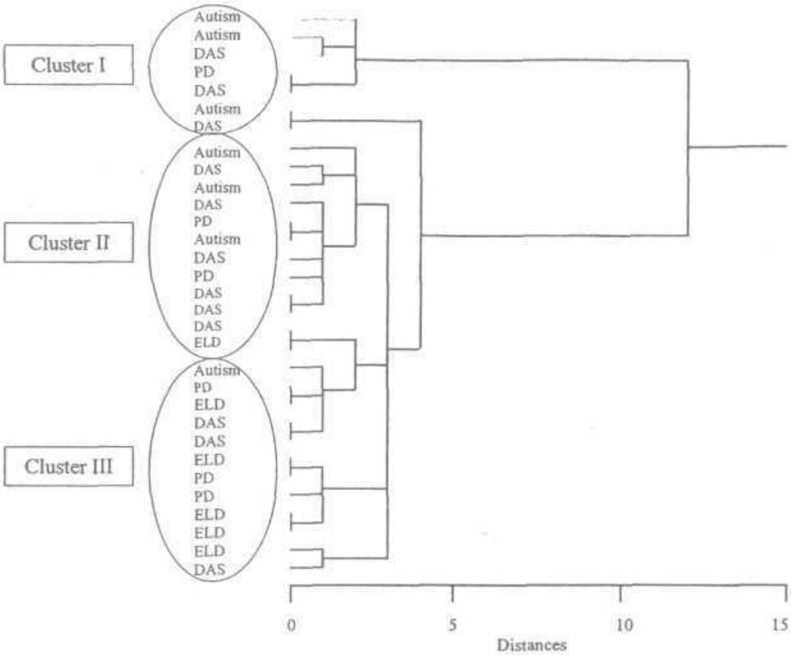

Figure 30a: Cluster tree depicting the Clusters I, II and III for Isolated oral movements

b) Sequential Oral Movements

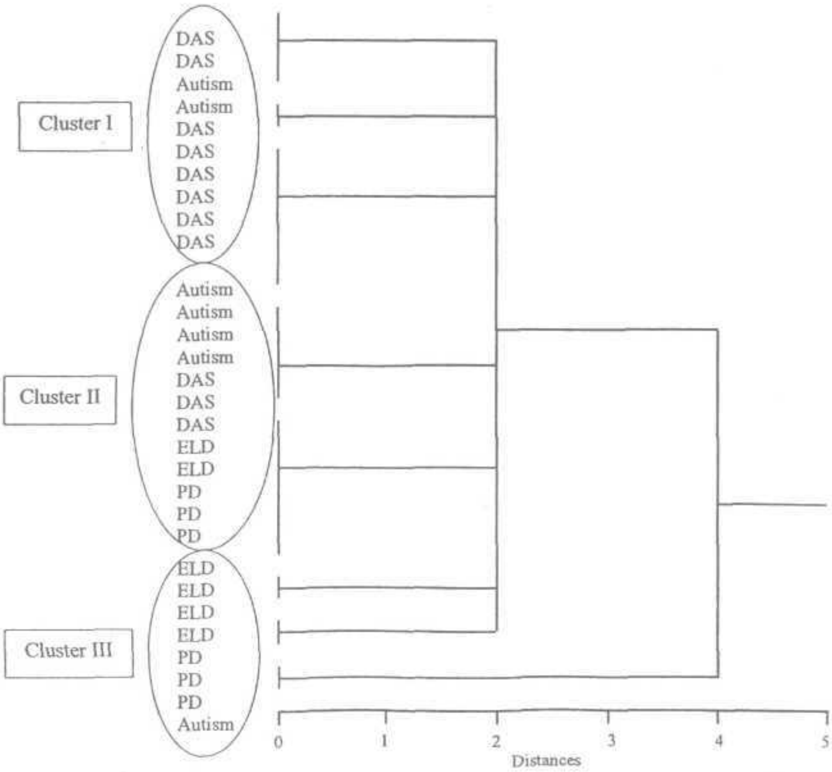

Figure 30b: Cluster tree depicting the Clusters I, II and III for Sequential Oral Movement tasks

3. Verbal Praxis Assessment

a) Isolated Verbal Movements

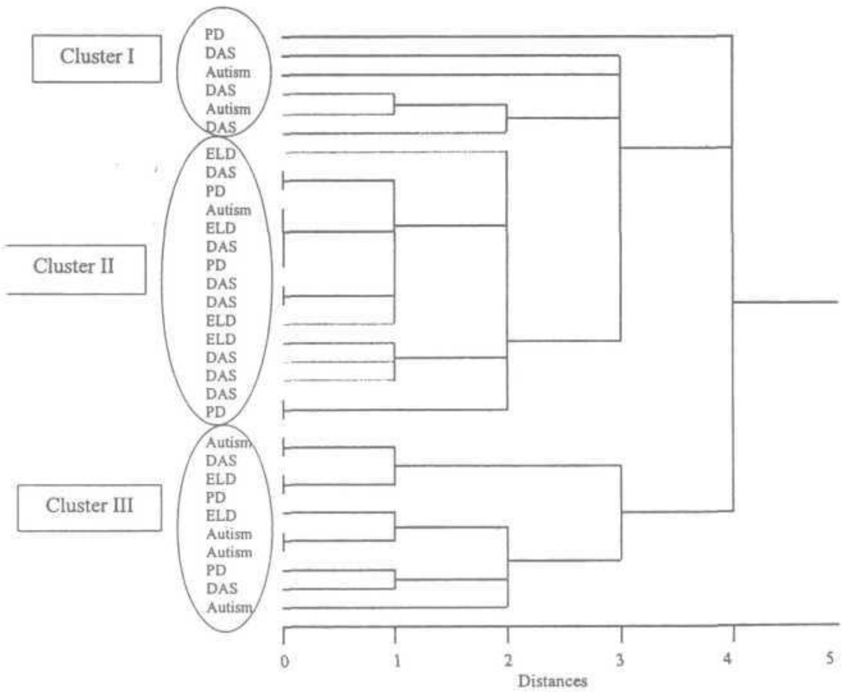

Figure 31a. Cluster tree depicting the Clusters I, II and III for isolated verbal movements.

b) Sequential Verbal Movements

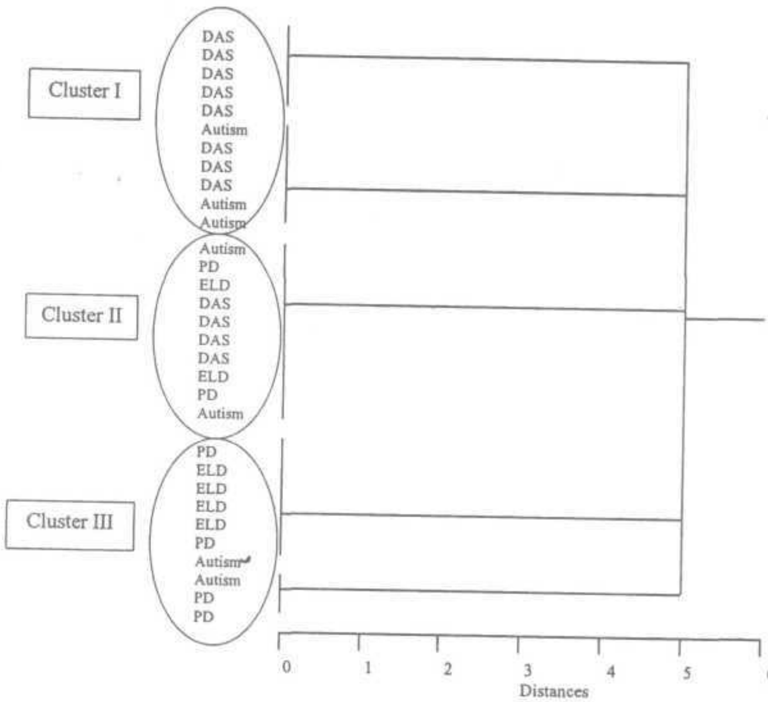

Figure 31b. Cluster tree depicting the Clusters I, II and III for sequential verbal tasks

1. Oral Motor Assessment

This section analyzed for oral structures at rest and function of oral mechanism for speech. The results of hierarchical clustering as is evident from Table 44 and figures 29a and 29b reveals that more number of participants with ELD and autism showed similar performance to participants with DAS when compared to those with PD. This is evident from the grouping of participants in clusters I and II depicting severe and moderate oral motor issues for the participants with DAS and sAOS.

2. Oral Praxis Assessment

Oral praxis was analyzed through tasks assessing isolated and sequential oral movements. As evident from table 44 and figures 30a and 30b, participants with PD and autism showed greater oral praxis deficits similar to participants with DAS, which is evident from the percentage of participants, clustered under the clusters I and II with severe and moderate oral praxis deficits.

3. Verbal Praxis Assessment:

In this section, participants with ELD and PD showed severe oral praxis deficits for isolated verbal movements similar to those with DAS, but for sequential verbal movements, participants with autism performed more similar to DAS group.

Overall, the assessment provided an insight into the presence of oral motor and praxis skill deficits in participants with sAOS and explored the possible co-occurrence of DAS in groups with sAOS, viz, ELD, PD and autism. Salient findings are summarized as follows:

1) Oral motor assessment:

- Oral motor assessment in groups with DAS and sAOS revealed poor scores in positioning of articulators, and placement of tongue in the mouth indicating the presence of mild hypotonia of the oral structures.
- Function of the oral mechanism for speech in terms of intra-oral breath pressure and precision for stops, fricatives and range and precision of movements of lip, jaw and tongue were affected in participants with sAOS similar to those with DAS.
- Participants with *Autism and ELD* from the suspected apraxic group exhibited greater oral motor issues similar to participants with *DAS.* Where as, participants with PD showed relatively lesser oral motor deficits when compared to participants with ELD and autism.

2) Oral praxis assessment

- Participants with DAS exhibited greater deficits in oral praxis skills in terms of both isolated movements, and sequential oral movements. Participants with Autism and PD showed greater oral praxis deficit for isolated oral movements similar to participants with DAS. Although the same trend was seen for sequential oral praxis task, participants with autism exhibited more difficulty in terms of accuracy and sequencing of double oro-motor movements similar to participants with DAS.

- A complex task such as sequential oral movements assessment served as clear indicators of praxis breakdown in terms of planning the oro-motor sequences in sAOS groups

3) Verbal praxis assessment

- Verbal praxis assessment was carried out employing hierarchical tasks including isolated, sequential verbal movements, word level, sentence level assessment and assessment of spontaneous speech.
- For isolated verbal movements assessment, speech sounds that involved predominantly tongue movements were most difficult for both groups of participants. Participants with ELD and PD had greater errors similar to participants with DAS unlike participants with autism.
- In sequential verbal movement task assessing verbal praxis skills, both groups with DAS and sAOS exhibited poorer accuracy and sequencing of two and three-sound movements. Participants with autism showed severe sequential disturbance in performing the sequential verbal movements similar to participants with DAS.
- In word level assessment, phonological process analysis revealed that participants with DAS exhibited greater numbers of different phonological processes both in terms of percentage occurrences and frequencies of individuals affected in the

different error categories, but were not significantly different from participants with sAOS. However, specific errors in the verbal praxis domain such as, sequencing errors, high degree of omissions, vowel errors, voicing errors, groping, and disfluencies, indicative of praxis breakdown were also observed in participants with sAOS. Sequence maintenance score was also calculated in all participants, which revealed significantly poorer sequence maintenance ability for participants with DAS than sAOS groups. Groups with PD and autism exhibited similar sequencing difficulty as those with DAS when compared to participants with ELD.

- Sentence level assessment reveal praxis deficits in terms of poorer PCC and PVC scores, and increased errors with increasing sentence lengths in participants with sAOS similar to participants with DAS.
- Assessment of spontaneous speech also revealed poorer PCC and PVC scores in addition to groping and disfluencies in participants with sAOS similar to participants with DAS.
- In assessment of spontaneous speech, phonotactic analysis revealed praxis breakdown in terms of the inability to use complex cluster patterns such as initial clusters, and medial non-geminated clusters. Furthermore, patters such as CVC syllables and multisyllabic words occurred less frequently in participants with DAS and sAOS. Similar trend in using simpler phonotactic patterns like medial geminated clusters, CV syllables, and bisyllabic words were evident in groups with sAOS and DAS.

In the assessment protocol, certain tasks assessing praxis skills were more sensitive in revealing the co-occurrence of praxis deficits in participants with sAOS similar to the results in participants with DAS. They are listed below:

- ✓ In isolated oral movements, movements in the category 'others' were more affected than tongue movements, serving as effective indicators for oral praxis deficits.
- ✓ Sequential Motor Score (SMS) from sequential oral and verbal movements
- ✓ Sequential Motor Score from word level praxis assessment
- ✓ Phonological error analysis indicating greater whole-word and timing errors compared to space errors in percentage occurrences of phonological processes
- ✓ Sequence maintenance score of sentence level praxis assessment
- ✓ Phonotactic analysis revealed greater frequency of occurrence of CV, V syllables, disyllabic words, geminated clusters and less frequently occurring CVC syllables, multisyllabic words, initial clusters, medial non-geminated clusters.

A perceptual assessment protocol assessing oral motor, oral praxis and verbal praxis skills was used to evaluate the praxis deficits in participants with DAS and compared with participants in sAOS groups, viz, ELD, PD and autism. Participants with sAOS showed co-occurring features of DAS revealing praxis breakdown similar to participants with DAS on all three skills.

Summary & Conclusions

SUMMARY AND CONCLUSIONS

Developmental apraxia of speech (DAS) is a neurological childhood speech sound disorder with impaired precision and consistency of movements underlying speech in the absence of neuromuscular deficits. Praxis breakdown is evident in various forms; primarily those of oral apraxia and / or verbal apraxia. The most commonly reported symptoms indicating DAS are deviant consonant and vowel productions, sequencing difficulties with phonemes and syllables, groping and trial-error behaviors, and inconsistency in articulation (Murdoch, Porter, Younger & Ozanne, 1984; Stackhouse, 1992; Hall, Jordan & Robin, 1993; Velleman & Strand, 1994; Thoonen et al., 1997).

There are concomitant disorders that are reported to share the dyspraxic characteristics (Deputy, 1984; Smit, 2004; Gillon & Moriarty, 2007). The co-occurrence of these disorders with DAS has led some to suggest a purely motoric basis for dyspraxic disorder (Robin, 1992). In addition, there is general agreement that language deficits also frequently accompany DAS. ASHA's (2007) technical report states that DAS occurs as a primary or secondary sign in children with complex neurobehavioral disorders (e.g. genetic, metabolic). Investigators have reported children with motor deficits along with academic and language deficits (Rosenbek & Wertz, 1972; Aram & Glasson, 1979; Ekelman & Aram, 1983; Snowling & Stack house, 1983; Milloy & Summers, 1989; Dewey & Kaplan, 1992), phonological disorders (Morley, 1965; Velleman & Strand, 1994; Mc Cauley, 2007), autism (DeMyer et al., 1981; Jones & Prior, 1985; Ohta, 1987; Rogers et al., 1996; Smith & Bryson, 1994; Marili, Andrianopoulos, Velleman &

Foreman, 2004), and stuttering (Yoss & Darley, 1974; Byrd & Cooper, 1989; Shriberg, Aram & Kwiatkowski, 1997a; McCabe, Rosenthal & McLeod, 1998; Hammer, 2002), presenting difficulty with praxis (voluntary movement) and sequencing tasks, suggesting a close relationship between praxis deficits and language-based skills.

This study was conducted to investigate for subgroups in DAS by means of exploring the co-occurrence of oral motor, oral praxis and verbal praxis deficits in Kannada speaking children with speech language disorders showing suspected apraxia of speech and presenting overlapping characteristic features seen in children with DAS, in the age range of 4 to 14 years. The study included two experimental groups. Experimental group I (DAS) constituted 12 children (4 males and 8 females) with a mean age of 5.9 years. This group was compared with experimental group II (sAOS) constituting nineteen (19) children with co-morbid speech and language disorders, viz, phonological impairment, expressive language disorder, and autism, identified as presenting suspected praxis deficits in the oral / verbal skills. sAOS group included six children each in ELD and PD groups and seven children with Autism. The assessment for sAOS groups was based on clinical observations made through 10 to 15 individual interactive therapy sessions by the investigator. After analyzing and reviewing for the presence of typical features of DAS, the participants in group II were selected based on their performance on the "screening checklist" (Refer Appendix I) administered by the investigator along with the detailed assessment of speech and language skills by another Speech Language Pathologist (SLP).

An assessment protocol was prepared to assess the oral motor, oral praxis and verbal praxis skills in the two groups of children with DAS and sAOS, in Kannada language. Items in the protocol were specifically designed to meet the needs of Kannada speaking children. The oral motor assessment protocol consisted of assessment of oral structures at rest and function of the oral structures during speech. Rating scales were used to analyze the different items in this section. The oral praxis section of the protocol comprised assessment of isolated and sequential oral movements that were also analyzed using rating scales. The verbal praxis assessment protocol assessed verbal tasks in a hierarchical manner from simple to complex tasks incorporating assessment of isolated verbal movements, sequential verbal movements, word level, sentence level and spontaneous speech. Isolated and sequential verbal movements were scored on the basis of rating scales. The other sections of the verbal praxis assessment protocol involved different types of analysis. Words were analyzed using phonological process analysis, presence of disfluencies, and groping and a rating scale to calculate the sequence maintenance score. Sentences were also analyzed by calculating sequence maintenance scores, and percentage of consonants and vowels correct (PCC and PVC). Spontaneous speech was analyzed by calculating PCC, PVC, presence of disfluencies and groping; and phonotactic analysis.

All participants in both groups (DAS and sAOS) were tested individually in a quiet, noise free environment. The audio-video recordings of the speech samples were carried out using a high fidelity digital video camcorder Sony 703E supplemented with audio recordings using a digital voice recorder, VY-H350. Positive feedback and appropriate cues were given in order to elicit the speech. The recorded audio-video samples were analyzed with the help of auditory and visual cues by using headphones after transferring them on to computer with 17 inches wide monitor. All samples were analyzed individually and scores were compiled in a scoring sheet with the help of different rating scales. The speech samples of the participants were analyzed separately subsequent to transcribing the speech samples using broad IPA transcription method. Reliability measures were done by two judges (Principal investigator and a second judge) in order to establish the reliability of the protocol, scores as per rating scales and that of IPA transcription. Statistical analyses were carried out to compare the participant groups for their performance across the three praxis skills assessed. Responses of all participants in the two groups (DAS and sAOS) for tasks assessing oral motor, oral praxis and verbal praxis skills were scored and analyzed. The salient findings of the study are summarized in the following section.

Results

Results are presented for each of the three sections of oral motor, oral praxis and verbal praxis skills. The findings are summarized as follows:

/. *Oral motor skills*

A. Oral structures at rest

> Children with DAS exhibited greater problems in oral motor skills than participants in sAOS groups (ELD, PD and autism). However the difference was not significant between the two groups.

- Children with DAS and sAOS performed similarly on oral motor praxis skills exhibiting oral motor deficits. Oral motor problems in both groups, I and II, were attributed to hypotonia and placement of oral structures such as lips, tongue, and jaw at rest.

B. Function of oral mechanism for speech

- Function of speech mechanism was affected alike for participants with DAS and sAOS in terms of imprecision and range of movements of lip, tongue, and jaw, air build up for stops, and fricatives.
- The two groups with DAS and sAOS did not differ significantly from one another in terms of function of oral structures during speech. Similar findings across DAS and sAOS were suggestive of co-occurrence of oral motor problems in sAOS groups.

The findings obtained for oral structures at rest and function of oral mechanism for speech was verified by employing cluster analysis which grouped the sAOS participants exhibiting similar characteristics and scores like participants with DAS, into three clusters that significantly differed from one another. Clustering of varying percentage of participants with DAS and sAOS under three different clusters pointed to the co-occurrence of oral motor issues in sAOS groups.

//. Oral praxis skills

A. Isolated oral movements

> Participants with DAS and sAOS exhibited poorest performance for 'other' movements (puffing up of cheeks and clearing of throat) followed by tongue movements.

> Participants with DAS differed significantly from those with ELD but not from participants with PD and autism.

> Greater errors in isolated oral movements were observed in participants with PD and autism similar to the DAS group. Participants with ELD exhibited relatively lesser errors but responses were suggestive of oral praxis deficits.

> Since impaired isolated oral movements could be due to deficits such as hypotonia of oral structures, sequential oral movements were also assessed to address the presence of praxis deficits

B. Sequential oral movements

> Individuals with DAS significantly differed from groups with PD and ELD for both MCS but did not differ significantly from participants with autism. In terms of SMS, DAS group did not differ significantly from any of the groups with sAOS.

phonological impairment, and expressive language disorder by comparing their performance with the reference group, DAS showing typical praxis deficits. Research is needed in future to comprehensively evaluate praxis deficits in individuals with suspected apraxia of speech. Future directions to fulfill this need may include:

- ✓ Objective measurements incorporating acoustic analysis and kinematic measures to evaluate oral and verbal praxis breakdown in individuals with suspected apraxia of speech.
- ✓ Large sample of participants with concomitant speech and language disorders exhibiting sAOS to study for the presence of co-occurring praxis deficits, thus facilitating generalization of the findings obtained in this study.

References

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition, Text Revision. Washington. DC: American Psychiatric Association.

American Speech-Language-Hearing Association (2002) *Childhood Apraxia of Speech* [Position Statement]. Retrieved May 10, 2007 from http://www.asha.org/docs/html/PS2007-00277.html.

American Speech-Language-Hearing Association. (2007). *Childhood Apraxia of Speech* [Technical Report]. Retrieved September 19, 2007 from http://www.asha.org/docs/html/TR2007-00278.html.

Amoroso, H. (1992). Disorders of vocal signaling in children. In H. Papousek, U. Jurgens & M. Papousek (Eds.), *Nonverbal vocal communication: Comparative and developmental approaches* (pp. 192-204). Cambridge, UK: Cambridge University Press.

Andrews, G., & Harris, M. (1964). The syndrome of stuttering. *Clinics in Developmental Medicine (No. 17).* London: Heinemann.

Aram, D. M. (1984). Assessment and treatment of developmental apraxia. *Seminars in Speech and Language, 5,* 66-70.

Aram, D. M., & Glasson, C. (1979). Developmental apraxia of speech. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association Meeting, Los Angeles, CA. In B. A. Lewis, L. A. Freebaim, A. Hansen, H. G. Taylor, S. Iyengar, and L. D. Shriberg (2004), Family pedigrees of children with suspected childhood apraxia of speech. *Journal of Communication Disorders, 37,* 157-175.

Aram, D. M., & Horwitz, S. (1983). Sequential and non-speech praxic abilities in developmental verbal apraxia. *Developmental Medicine and Child Neurology, 25,* 197-206.

Aram, D. M. & Nation, J.E. (1982). *Child Language Disorders.* St. Louis, MO: CV Mosby.

Ayres, J. A. (1972). *Sensory Integration and Learning Disorders.* Los Angeles: Western Psychological Services.

Ayres, J. A. (1985). *Developmental Dyspraxia & Adult-Onset Apraxia: A Lecture* Prepared for Sensory Integration Internationa/ (Paperback - Dec 1985).

Ball, M. J. & Gibbon, F. (2002). *Vowels and Vowel Disorders.* Woburn, MA: Butterworth-Heinemann.

Baltaxe, C. A. M. (1984). Use of contrastive stress in normal, aphasic, and autistic children. *Journal of Speech and Hearing Research, 27,* 97-105.

Bankson, N. W. & Bernthal, J. E. (1998). Phonological assessment procedures. In J. E. Bernthal and N. W. Bankson (Eds) *Articulation and phonological disorders,* 4th edition (Boston: Allyn & Bacon), pp. 233-269.

Banumathy, N., & Manjula, R. (2007). *Effect of length, mode and type of linguistic units on vowel duration in the speech of developmental apraxia of speech.* Paper presented at the 35th All India Conference of Dravidian Linguists, June 2007, Mysore, Karnataka, India.

Bartolucci, G., & Pierce, S. (1977). A preliminary comparison of phonological development in autistic, normal, and mentally retarded subjects. *British Journal of Disorders of Communication, 21,* 137-147.

Bartolucci, G., Pierce, S., Streiner, D., & Eppel, P. T. (1976). Phonological investigation of verbal autistic and mentally retarded subjects. *Journal of Autism and Childhood Schizophrenia, 6,* 303-316.

Bernstein Ratner, N. (1995). Treating the child who stutters with concomitant language or phonological impairment. *Language, Speech, and Hearing Services in Schools,* 25,180-186.

Bernthal, J. E., & Bankson, N. W. (1993). *Articulation and phonological disorders.* (3rd Ed.)Boston: Prentice Hall.

Bernthal, J.E., & Bankson, N.W. (1998). *Articulation and phonological disorders.*(4th ed.) Boston: Allyn and Bacon.

Berry, M. (1938). The developmental history of stuttering children. *The Journal of Paediatrics, 12,* 209-217.

Blakeley, R. W. (1980). *Screening Test for Developmental Apraxia of Speech.* Tigard, OR: C.C. Publications, Inc.

Blakely, R. (2001). *Screening Test for Developmental Apraxia of Speech—Second Edition.* Austin, TX: Pro-Ed.

Bleile, K., & Schwarz, I. (1984). Three perspectives on the speech of children with Down's syndrome. *Journal of Communication Disorders, 17,* 87'-94.

Bleile, K.M. (2004). *Manual of articulation and phonological disorders. Infancy through Adulthood.* Second Edition. San Diego: Singular Publishing Group, Inc.

Blood, G. W. & Seider, R. (1981). The concomitant problems of young stutterers. *Journal of Speech and Hearing Disorders, 46,31-33.*

Bloodstein, O. (1995). *A handbook on stuttering*, fifth edition (San Diego, CA: Singular).

Boucher, J. (1976). Articulation in early childhood autism. *Journal of Autism and Childhood Schizophrenia, 6,* 297-302.

Bowen. (2006). Childhood Apraxia of Speech: information for families. Retrieved August 24, 2005 from http://www.apraxia-kids.org.

Bowman, S. N., Parsons, C. L., & Morris, D. A. (1984). Inconsistency of phonological errors in developmental verbal dyspraxic children as a factor of linguictis task and performance load. *Australian Journal of Human Communication Disorders, 12,* 109-119.

Bradford, A., & Dodd, B. (1996). Do all speech-disordered children have motor deficits? *Clinical Linguistics and Phonetics, 10,* 77-101.

Branigan, G. (1976). Syllabic structure and the acquisition of consonants: The great conspiracy in word formation. *Journal of Psycholinguistic Research, 5(2),* 117-133.

Bridgeman, E., & Snowling, M. (1988). The perception of phoneme sequence: A comparison of dyspraxic and normal children. *British Journal of Disorders of Communication. 23,* 245-252.

Brooks, V. B. (1986). *The neural basis of motor control.* New York: Oxford University Press.

Byrd, K., & Cooper, E. B. (1989). Apraxic speech characteristics in stuttering, developmentally apraxic, and normally speaking children. *Journal of Fluency Disorders, 14(3),* 215-229.

Campbell, T., & Shriberg, L. D. (1982). Associations among pragmatic functions, linguistic stress, and natural phonological processes in speech-delayed children. *Journal of Speech and Hearing Research, 25,* 547-553.

Caruso, A. & Strand, E. (1999). *Clinical Management of Motor Speech Disorders in Children.* New York: Thieme.

Cohen, M. M., Jr. (1995). Syndrome delineation and heterogeneity. In R. J. Gorlin, H. V. Toriello, & M. M. Cohen, Jr. (Eds.), *Hereditary hearing loss and its syndromes* (pp. 5 -8). New York: Oxford University Press.

Conture, E. G., Louko, L. J., & Edwards, M. L. (1993). Simultaneously treating stuttering and disordered phonology in children: Experimental treatment, preliminary findings. *American Journal of Speech-Language Pathology, 2*, 72- 81.

Crary, M. A. (1982). *Developmental verbal dyspraxia: A phonological perspective.* Miniseminar presented at the annual meeting of the American Speech and Hearing Association, Toronto.

Crary, M. A. (1984). Phonological characteristics of developmental verbal dyspraxia. *Seminars in Speech and* Language, 5:71-83.

Crary, M. A. (1993). *Developmental Motor Speech Disorders,* Singular Publishing Group, Inc., SanDiego, CA.

Crary, M. A. (1995). Clinical evaluation of developmental motor speech disorders. *Seminars in Speech and Language, 16*, 110-125.

Crary, M. A., & Anderson, P. (1991). *Speech and motor performance in developmental apraxia of speech.* Technical session presented at the annual convention of the American-Speech-Language-Hearing Association, Atlanta, GA.

Crary, M. A., Landess, S., & Towne, R. (1984). Phonological error patterns in developmental verbal dyspraxia. *Journal of Clinical Neuropsychology, 6,* 2, 157-170.

Cress, C, Sterup, G., & Hould, T. (2003). *Adapted phonological assessment for young children with severe impairments.* Paper presented at the American Speech-Language-Hearing Association Convention, Chicago, IL. (available at http://www.unl.edu/barkley/present/cress/847.pdf).

Cumley, G. (2002). *Children with Apraxia and the Use of Augmentative and Alternative Communication.* Retrieved September 23, 2005 from http.V/www.apraxia-kids.org/site/apps/nlnet/content2.

Darley, F. L. (1955). The relationship of parental attitudes and adjustments to the development of stuttering. In W. Johnson and R. R. Leutenegger (Eds.), *Stuttering in children and adults* (Minneapolis: University of Minnesota Press), pp. 74-153.

Darley, F.L., Aronson, A.E., Brown, J.R. (1975). *Motor Speech Disorders.* Philadelphia, PA: W.B. Saunders

Davis, B. L., Jacks, A., & Marquardt, T. P. (2005). Vowel patterns in developmental apraxia of speech: Three longitudinal case studies. *Clinical Linguistics and Phonetics, 19(4),* 249-274.

Davis, B. L., Jakielski, K. L., & Marquardt, T. P. (1998). Developmental Apraxia of Speech: determiners of differential diagnosis. *Clinical Linguistics and Phonetics, 12,* 25-45.

Davis, B. L., Strand, E. A., & Velleman, S. (1998). *Management of developmental apraxia of speech: Linguistic and motor perspectives.* Paper presented at the convention of the American Speech-Language-Hearing Association, San Antonio, TX.

Davis, B. L., & Velleman, S. L. (2000). Differential diagnosis and treatment of Developmental Apraxia of Speech in infants and toddlers. *Infant-Toddler Intervention,* 10, 3, 177-192.

DeMyer, M. K., Hingtgen, J. N., & Jackson, R. K. (1981). Infantile autism reviewed: A decade of research. *Schizophrenia Bulletin, 7,* 388- 451.

DeMyer, M.K., Alpern, G.D., Barton, S., DeMyer, W.E., Churchill, D.W., Hingtgen, J.H., Bryson, C.Q., Pontius, W., & Kimberlin, C. (1972). Imitation in autistic, early schizophrenic, and non-pyschotic subnormal children. *Journal of Autism and Childhood Schizophrenia, 2,* 264-287.

Deputy, P.N. (1984). The need for description in the study of developmental verbal dyspraxia. *Australian Journal of Human Communication Disorders, 12,* 3-13.

Dewey D. (1995) What is developmental dyspraxia? *Brain and Cognition, 29(3),* 254-74.

Dewey, D., & Kaplan, B.J. (1992). Subtyping of Developmental motor deficits. *Journal of Clinical and Experimental Neuropsychology, 14,* 50-64.

Dewey D., Roy E. A., Square-Storer P. A., & Hayden, D. (1988). Limb and oral praxic abilities of children with verbal sequencing deficits. *Developmental Medicine and Child Neurology, 30,* 743-751.

Dewey, D., & Wilson, B. N. (2001). Developmental coordination disorder: what is it? *Physical and Occupational Therapy in Pediatrics, 20,* 5-27.

Dodd, B. (1976). A comparison of the phonological systems of mental age matched, normal, severely subnormal and Down's syndrome children. *British Journal of Disorders of Communication, 11(1),* 27-42.

Dodd, B. J. (1995). *Differential diagnosis and treatment of children with speech disorder.* London: Whurr.

Dodd, B. J. & Bradford, A. (2000). A comparison of three therapy methods for children with different types of developmental phonological disorder. *International Journal of Language and Communication Disorders, 35,* 189-209.

Dodd, B., & McCormack, P. (1995). A model of speech processing of phonological disorders. In B. Dodd (Ed.), *The Differential Diagnosis and Treatment of Children with Speech Disorder* (pp. 65-89). San Diego, CA: Singular Publishing Group.

Dore, J., Franklin, M. B., Miller, R. T., & Ramer, A. L. H. (19760. Transitional phenomena in early langugae acquisition. *Journal of Child Language, 3,* 13-28.

Dunn, C. & Davis, B.L. (1983). Phonological process use in phonologically disordered children. *Applied Psycholinguistics, 4,* 187-201.

Edwards, M. (1973). Developmental verbal dyspraxia. *British Journal of Disorders of Communication, 8* (1), 64-70.

Edwards, M. (1984). *Disorders of articulation.* Vienna: Springer- Verlag.

Edwards, M. L., & Shriberg, L. D. (1983). *Phonology: Applications in communicative disorders.* San Diego: College-Hill.

Eisenmajer, R., Prior, M., Leekam, S. Wing, L., Gould, J., Welham, M., et al. (1996). Comparison of clinical symptoms in autism and Asperger's disorder. *Journal of the American Academy of Child and Adolescent Psychiatry,* 55(11), 1523-1529.

Eisenson, J. (1972). *Aphasia and language disorders in children.* New York: Harper & Row.

Ekelman, B. L., & Aram, D. M. (1983). Syntactic findings in developmental verbal apraxia. *Journal of Communication Disorders,* 16, 237-250.

Ekelman, B. L., & Aram, D. M. (1984). Spoken syntax in children with developmental verbal apraxia. *Seminars in Speech and Language, 5(2),* 97-109.

Farmer, A., & Brayton, E. R. (1979). Speech characteristics in fluent and dysfluent Down syndrome adults. *Folia Phonatrica, 31,* 284-290.

Fee, J., & Ingram, D. (1982). Reduplication as a strategy of phonological development. *Journal of Child Language, 9 (1),* 41-54.

Felsenfeld, S. (1997). Epidemiology and genetics of stuttering. In R. F. Curlee and G. M. Siegel (Eds), *Nature and treatment of stuttering: New directions,* second edition (Boston: Allyn & Bacon), pp. 3-23.

Ferguson, C. (1983). Reduplication in child phonology. *Journal of Child Language, 10(1),* 239-244.

Ferguson, C. A., & Farwell, C. B. (1975). Words and sounds in early language acquisition. *Language, 51*, 419-439.

Ferguson, C.A. (1978). Learning to pronounce: The earliest stages of phonological development in the child. In F.D. Minifie & L.L. Lloyd (Eds.). *Communicative and cognitive abilities - early behavioural assessment,* (pp. 273-297). Baltimore: University Park Press.

Ferry, P., Hall, S., & Hicks, J. (1975). "Dilapidated" speech: Developmental Verbal dyspraxia. *Developmental medicine and child neurology, 17,* 749-756.

Folkins, J. & Bleile, K. (1990). Taxonomies in Biology, Phonology, and Speech Motor Control. *Journal of Speech and Hearing Disorders, 55, 596-611.*

Foreman, C. G. (2001). *The Use of Contrastive Focus by High-Functioning Children with Autism.* Unpublished Doctoral Dissertation, University of California, Los Angeles.

Forrest, K. (2002). Are oral-motor exercises useful in the treatment of phonological/articulator disorders? *Seminars in Speech and Language, 23,* 15-25.

Forrest, K. (2003). Diagnostic criteria of Developmental Apraxia of Speech used by Clinical Speech-Language Pathologists. *American Journal of Speech-Language Pathology, 12,* 376-380.

Forrest, K., & Elbert, M. (2001). Treatment for phonologically disordered children with variable substitution patterns. *Clinical Linguistics and Phonetics, 15,* 41-45.

Forrest, K., & Morrisette, M. L. (1999). Feature analysis of segmental errors in children with phonological disorders. *Journal of Speech, Language, and Hearing Research, 42,* 187-194.

Gavan, J., & Olson, R. K. (2003). Genetic and environmental influences on individual differences in printed word recognition. *Journal of Expressive Child Psychology, 84:* 97-123.

Gerber, S. E. (1990). *Prevention: The etiology of communicative disorders in children.* Englewood Cliffs, NJ: Prentice - Hall.

Gillon, G. (2000). *The efficacy of phonological awareness intervention for children with spoken language impairment. Language, Speech, and Hearing Services in Schools, 31,* 126-141.

Gillon, G. (2006). Phonological awareness intervention: A preventive framework for preschool children with specific speech and language impairments. In R. McCauley & M. Fey (Eds.), *Treatment of language disorders in children* (pp. 279-308). Baltimore: Paul Brookes.

Gillon, G. T. (2004). *Phonological Awareness: From Research to Practice.* New York: Guilford Press.

Gillon, G. T., & Moriarty, B. C. (2006). Phonological awareness intervention for children with childhood apraxia of speech, *International Journal of Communication Disorders, 41 (6);* 713-734.

Gillon, G. T., & Moriarty, B. C. (2007). Childhood apraxia of speech: Children at risk for persistent reading and spelling disorder. *Seminars in Speech and Language, 28,* 48-57.

Gracco, V. L. (1987). A multilevel control model for speech motor activity. In H. Peters & W. Hulstijn (Eds.), *Speech Motor Dynamics in Stuttering* (pp. 57-76). New York: Springer-Verlag.

Gracco, V. L. (1991). Sensorimotor mechanisms in speech motor control. In H. F. M. Peters et al. (Eds): *Speech motor control and stuttering.* Proceedings of the 2nd Conference on Speech motor control and stuttering, (pp 53-76) Nijmegen, Netherlands. Excerpta Medica, Amsterdam.

Gracco, V.L, & Abbs, J.H. (1987). Programming and Execution processes of speech movement control: Potential neural correlates. In M.R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders,* (pp 1-25). New York: Thieme Medical Publishers, Inc.

Green, J. R., Moore, C. A., & Reilly, K. J. (2002). The sequential development of jaw and lip control for speech. *Journal of Speech, Language, and Hearing Research, 45,* 66-79.

Grunwell, P. (1982). The development of phonology: A descriptive profile. *First Language,* J, 161-191.

Grunwell, P. (1987). *Clinical Phonology.* Baltimore, MD: Williams & Wilkins.

Grunwell, P. (1997). Natural phonology. In M. Ball & R. Kent (Eds.), *The new phonologies: Developments in clinical linguistics.* San Deigo: Singular Publishing Group, Inc.

Gubbay, S. S. (1978). The management of developmental apraxia. *Developmental Medicine and Child Neurology, 20(5):643-6.*

Guyette, T. W., & Diedrich, W. M. (1981). A critical review of developmental apraxia of speech. In N. J. Lass (Ed.), *Speech and language: Advances in basic research and practice* (Vol. 5, pp. 1-49). New York: Academic Press.

Hall, P. K. (1989). The occurrence of developmental apraxia of speech in a mild articulation disorder: A case study. *Journal of Communication Disorders, 22,* 265-276.

Hall, P. K. (2000a). Part I: Speech characteristics of the disorder. *Language, Speech, & Hearing Services in Schools, 31 (2),* 169-172.

Hall, P. K. (2000b). Part II: The nature and causes of DAS. *Language, Speech, & Hearing Services in* Schools, *31 (2),* 173-175.

Hall, P. K. (2000c). Part III: Other problems often associated with the disorder. *Language, Speech, & Hearing Services in* Schools, *31 (2),* 176-178.

Hall, P. K., Hardy, J. C, & Lavelle, W. E. (1990). A child with signs of DAS with whom a palatal lift prosthesis was used to manage palatal dysfunction. *Journal of Speech and Hearing Disorders, 55,* 454-460.

Hall, P., Jordan, L., & Robin, D. (1993). *Developmental Apraxia of Speech: Theory and Clinical Practice.* Austin, TX, Pro-Ed.

Hamilton, C. (1993). Investigation of articulatory patterns of young adults with Down syndrome. *Down syndrome: Research and Practice,* 7(1), 10-14. Retrieved September 10, 2005 from http://www.downsyndrome.info/library/periodicals /dsrp/01/l/015/DSRP-01-l-015-EN-GB.html

Hammer, D. (2002). *Apraxia of Speech in Young Children.* Presented at the Childhood Apraxia of Speech Association/Hendrix Foundation workshop. Houston, Texas. Retrieved May 24, 2005 from http://www.apraxia-kids.org/site/apps/nl/content3.

Hammes, J. & Langdell, T. (1981). Precursors of symbol formation and childhood autism. *Journal of Autism and Developmental Disorders, 11,* 331-346.

Hardan, A., Kilpatrick, B., Keshavan, M., & Minshew, M. (2003). Motor performance and anatomic magnetic resonance imaging (MRI) of the basal ganglia in autism. *Journal of Child Neurology, 18,* 317-24.

Hayden, D. & Square, P. (1999). *Verbal Motor Production Assessment for Children.* The Psychological Corporation.

Hayden, D. (1994). Differential diagnosis of motor speech dysfunction in children. In P.A. Square (Issue Editor) *Developmental apraxia of speech.* Thieme, NY.

Hayden, D. (2002). "How do we help children with apraxia become 'risk-takers' with their speech and communication?" *The Apraxia-Kids Monthly, 3* (10). December. Retrieved from http://www.apraxia-kids.org/site/apps/nl/content3.

Hayden, J. C, & Square, P. A. (1993). *A systems approach for the differential diagnosis of developmental apraxia of speech.* A seminar presented at the annual convention of the American Speech-Language-Hearing Association, November, Anaheim, CA.

Haynes, S. (1985). Developmental apraxia of speech: Symptoms and treatment. In D. F. Jons (Ed.), *Clinical management of neurogenic communicative disorders* (pp. 259-266). Boston: Little, Brown.

Henderson, L., Rose, P., & Henderson, S. (1992). Reaction time and movement time in children with a Developmental Coordination Disorder. *Journal of Child Psychology and Psychiatry, 33,* 895-905.

Herbert, M. R., Ziegler, D. A., Deutsch, C. K., O'Brien, L. M., Lange, N., Bakardjiev, A., et al. (2003). Dissociations of cerebral cortex, subcortical and cerebral white matter volumes in autistic boys. *Brain, 126(5),* 1182-1192.

Herrmann, J., & Opitz, J. M. (1974). Naming and nomenclature of syndromes. *Birth Defects, 10,* 69-86.

Hertrich, I. & Ackerman, H.. (2000). Lip-jaw and tongue-jaw coordination during rate-controlled syllable repetition. *Journal of Acoustical Society of America, 107(4),* 2236-2247.

Hertzig, M., Snow, M, & Sherman, M. (1989). Affect and cognition in autism. *Journal of the American Association for Child and Adolescent Psychiatry, 28,* 195-199.

Hesselwood, B. C, Bray, M, & Crookston, I. (1995). Juncture, rhythm, and planning in the speech of an adult with Down's syndrome. *Clinical Linguistics and Phonetics, 9,* 121-137.

Hickman, L. (2000). *Apraxia Profile.* San Antonio, TX: The Psychological Corporation.

Hiremath, R. C. (1980). *The Structure ofKannada.* Dharwad: Prasanga.

Hodge, M. A. (1994). Assessment of children with developmental apraxia of speech: A rationale. *Clinics in Communication Disorders, 4,* 91-101.

Hodson, B. (2004). *Hodson Assessment of Phonological Patterns (HAPP-3),* 3rd ed. Austin, TX: Pro-Ed linguisystems

Hodson, B., & Paden, E. (1981). Phonological processes which characterise intelligible and unintelligible speech in early childhood. *Journal of Speech and Hearing Disorders, 46,* 369-373.

Horwitz, S. J. (1984). Neurological findings in developmental verbal apraxia. In W. H. Perkins & J. L. Northern (Eds.,), *Seminars in speech and language* (pp. 111-118). New York: Thieme-Stratton.

Hustad, K. C, & Beukelman, D. R. (1998). *Integrating residual natural speech andAAC.* Paper presented at the convention of the American Speech-Language-Hearing Association, San Antonio, TX.

Ingram, D. (1989). *Phonological disability in children.(2nd* ed.). London: Cole & Whurr, Ltd.

Ingram, D. (2002). Commentary on "Evaluating articulation and phonological disorders when the clock is running." *American Journal of Speech-Language Pathology, J,* 257-258.

Itoh, M. & Sasanuma, S. (1984). Articulatory movements in apraxia of speech. In Rosenbek J.c. Mcneil, M.R, Aronson, E.,eds. *Apraxia of Speech: Physiology, Acoustics, Linguistics, Management.* sanDeigo: College Hill.

Jackson, M.R.F. & Hall, P.K. (1987). *A longitudinal study of articulation characteristics in developmental apraxia of speech.* Paper presented at the annual meeting of the American Speech-Language-Hearing Association, New Orleans, LA.

Jacks, A., Marquardt, T.P., Davis, B.L. (2006). Consonant and syllable structure patterns in childhood apraxia of speech: developmental change in three children. *Journal of Communication Disorders, 39,* 424-41.

Jaffe, M. (1986). Neurologic impairments of speech production: Assessment and treatment. In J. Costello & A. Holland (Eds.), *Handbook of Speech and Language Disorders* (pp. 157-186). San Diego: College Hill Press.

Jakobson, L.S., & Goodale, M.A. (1991). Factors affecting higher-order movement planning: a kinesthetic analysis of human comprehension. *Exceptional Brain Research, 86,* 199-208.

Jelm, J. M. (2001). *Verbal Dyspraxia Profile.* DeKalb, IL: Jannelle Publications.

Johnson, A. & Jacobson, B. (1998) *Medical Speech Language Pathology: A Practitioner's Guide.* Thieme.

Jones, V. & Prior, M. (1985). Motor imitation ability and neurological signs in autistic children. *Journal of Autism and Developmental Disorders, 15,* 37- 46.

Jorgensen, R. J. (1989). Problems in nomenclature of craniofacial disorders. *Journal of Craniofacial Genetics and Developmental Biology, 9,* 7-20.

Kaufman, N. (1995). *Kaufman Speech Praxis Test.* Detroit, MI: Wayne State University Press.

Kaufman, N. (2002). *Evaluation and treatment of children with apraxia of speech.* Northern Speech/National Rehab Continuing Education Seminar, Milwaukee, WI. Retrieved June 1, 2006 from http://www.apraxia-kids.org/site/apps/nlnet/content2.

Kearns, K. P. (1990). Broca's aphasia. In L. L. LaPointe (Ed.), *Aphasia and related neurogenic language disorders* (pp. 1-37). New York: Thieme Medical.

Kent, R, D. (1976). Anatomical and neuromuscular maturation of the speech mechanism: evidence from acoustic studies. *Journal of Speech and Hearing Research, 19,* 421-447.

Kent, R. D. (1984). Facts about stuttering: neuropsychologic perspectives. *Journal of Speech and Hearing Disorders, 48,* 249-255.

Kent, R. D. (1992). The biology of phonological development. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 65-90). Timonium, MD: York.

Kent, R.D. (1997). Speech motor models and developments in neurophysiological science: new perspectives. In W. Hulstijn, H.F.M. Peters, and P.H.H.M. van Leishout. (Eds), *Speech production, motor control, brain research and fluency disorders,* (PP. 13-36). Amsterdam: Elsevier.

Kent, R. D. (2000). Research on speech motor control and its disorders: A review and prospective. *Journal of Communication Disorders, 33,* 391-428.

Kent, R. D., Adams, S. G., & Turner, G. S. (1996). Models of speech production. In: Lass NJ, (Ed.). *Principles of Experimental Phonetics*. Baltimore, MD: Mosby, 3—45.

Kent, R.D., & Forner, L.L. (1980). Speech segment durations in sentence recitation by children and adults. *Journal of Phonetics,* 8, 157-168.

Kent, R.D., & McNeil, M.R., (1987). Relative timing of sentence repetition in apraxia of speech and conduction aphasia. In Ryalls, J.H., (Ed.). *Phonetic approaches to speech production in aphasia and related disorders.* Boston: Little, Brown and Company.

Kent, R. D., & Rosenbek, J. C. (1983). Acoustic patterns of apraxia of speech. *Journal of Speech and Hearing Research,* 26, 231-249.

Kirkpatrick, E., & Ward, J. (1984). Prevalence of articulation errors in NSW school pupils. *Australian Journal of Human Communication Disorders, 12,* 55-62.

Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes, 16,* 287-308.

Kumari, B. S., & Mallikarjun, B. (1985). *Pictorial glossary in Kannada.* CIIL Publications, Mysore

Kumin, L., & Adams, J. (2000). Developmental apraxia of speech and intelligibility in children with Down syndrome. *Down Syndrome Quarterly,* 5(3), 1-7.

Layton, T. (2001). Young children with Down syndrome. In T. Layton, E. Crais & L. Watson (Eds.), *Handbook of early language impairment: Nature* (pp. 302-360). Albany, New York: Delmer publishers.

Leonard, L. B. (1992). Models of phonological development and children with phonological disorder. In C. A. Ferguson, L. Menn, and C. Stoel-Gammon (Eds.), *Phonological Development: Models, research, implications* (pp. 495-507). Timonium, MD: York Press.

Leonard, L. B., Shwartz, R. G., Swanson, I. A., & Frome-Loeb, D. M. (1987). Some conditions that promote unusual phonological behaviour in children. *Clinical Linguistics and Phonetics, 1 (1),* 23-34.

Leonard,L. B. & McGregor,K. (1991). Unusual phonological patterns and their underlying representations: a case study. *Journal of Child Language, 18,* 261-27ʳl.

Levelt, W.M. (1989). *Speaking: From intention to articulation,* Cambridge: MIT Press.

Lewis, B. A., Freebairn, L. A., Hansen, A. J., Iyengar, S. K., & Taylor, H. G. (2004) School age follow-up of children with childhood apraxia of speech. *Language, Speech and Hearing Services in Schools, 35,* 122-140.

Lleo, C. (1990). Homonymy and reduplication: On the extended availability of two strategies in phonological acquisition. *Journal of Child Language, 17 (2),* 267-278

Locke, J. L. (1993). *The child's path to spoken language.* Cambridge, MA: Harvard University Press.

Long, A. D., Bahr, D. C, & Kumin, L. (1998). *The battery for oral-motor behavior in children* (unpublished test). Baltimore: Loyola College.

Louko, L. J., (1995), Phonological characteristics of young children who stutter. *Topics in Language Disorders, 15,* 48-59.

Louko, L. J., Conture, E. G. & Edwards, M. L., (1999), Treating children who exhibit co-occurring stuttering and disordered phonology. In R. F. Curlee (Ed.), *Stuttering and related disorders ofXuency,* second edition (New York: Thieme Publishers), pp. 124-138.

Louko, L. J., Edwards, M. L.& Conture, E. G., (1990), Phonological characteristics of young stutterers and their normally Fluent peers: Preliminary observations. *Journal of Fluency Disorders, 15,* 191-210.

Love, R. & Fitzgerald, M. (1984). Is the diagnosis of developmental apraxia of speech valid? *Australian Journal of Human Communication Disorders,* 72:71-82.

Love, R. J. (1992). Developmental verbal dyspraxia. In R. J. Love, *Childhood motorspeech disability* (pp. 94-111). New York: Macmillian.

Love, R. J. (2000) *Childhood Motor Speech Disorders.* Second Edition, Allyn & Bacon.

Lowe, R. J. (1984). *Phonology: Assessment and intervention applications in speech pathology.* Baltimore: Williams and Wilkins.

Lucker-Lazerson, N. (2002). *Apraxia? Dyspraxia? Articulation? Phonology? What Does it All Mean? An Introduction to Speech Production Disorders,* Apraxia-Kids Retrieved, March 14, 2005, http://www.apraxia-kids.org/slp/luckerlazerson.html

Maassen B. (2002). Issues contrasting adult acquired versus developmental apraxia of speech. *Seminars in Speech and Language.* 23, 4, 257-266.

Maassen, B., Groenen, P., & Crul, T. (2003). Auditory and phonetic perception of vowels in children with apraxic speech disorders. *Clinical Linguistics and Phonetics, 17,* 447-467.

Maassen, B., Nijland, L. & van der Meulen, S. (2001). Coarticulation within and between syllables by children with developmental apraxia of speech. *Clinical Linguistics & Phonetics, 15(1),* 145- 150.

Mackay, L., & Hodson, B. (1982). Phonological process identification of misarticulations of mentally retarded children. *Journal of Communication Disorders, 15,* 243-250.

Macken, M.A. (1979). The child's lexical representations: the 'puzzle - puddle - pickle' evidence. *Journal of Linguistics, 16,* 1-17.

Macken, M. A. (1987). Representation, rules and overgeneralization in phonology. In B. MacWhinney (Ed.)., *Mechanisms of Language acquisition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Macken, M. A. & Ferguson, C. A. (1983). Cognitive aspects of phonological development: model evidence and issues. In K. E. Nelson (Ed.). *Children's Language,* vol. 4 (Hillsdale, NJ: Lawrence Erlbaum Associates).

MacNeilage, P. F., & Davis, B. L. (1990). Acquisition of speech production: Frames, then content. In M. Geannerod (Ed.), *Motor representation and control* (Vol. XIII, pp. 453^75). Hillsdale, NJ: Erlbaum.

Marili, K. E., Andrianopoulos, M. V., Velleman, S. L., & Foreman, C. G. (2004). *Incidence of motor speech impairment in autism and Asperger's disorders.* Paper presented at the American Speech-Hearing-Language Association Convention, November. Philadelphia.

Marion, M. J., Sussman, H. M., & Marquardt, T. P. (1993). The perception and production of rhyme in normal and developmentally apraxic children. *Journal of Communication Disorders,* 26, 129-160.

Marquardt, T., Dunn, C, & Davis, B. (1985). Apraxia of speech in children. In J. Darby (Ed.), *Speech and language evaluation in neurology: Childhood disorders* (pp. 113-132). New York: Gruner & Stratton.

Marquardt, T., Jacks, A., & Davis, B. L. (2004). Token-to-token variability in developmental apraxia of speech: three longitudinal case studies. *Clinical Linguistics and Phonetics, 18,* 127-144.

Marquardt, T.M., & Sussman, H.M. (1991). Developmental apraxia of Speech: Theory and practice, hi D. Vogel, & M. Cannito (Eds.), *Treating disordered speech motor control* (pp. 341-390). Austin, TX: Pro-Ed.

Marquardt, T.P. & Sussman, H.M., (1993). The perception and production of rhyme in normal and developmentally apraxic children. *Journal of Communication Disorders, 26(3):* 129-60.

Marquardt, T. P., Sussman, H. M. & Davis, B. L. (2001). Developmental apraxia of speech: Advances in theory and practice. In D. Vogel and M. Cannito (Eds) *Treating Disordered Motor Speech Control,* second edition (Austin, TX: Pro-Ed).

Marquardt, T. P., Sussman, H. M., Snow, T., & Jacks, A. (2002). The integrity of the syllable in developmental apraxia of speech. *Journal of Communication Disorders, 35,* 31-49.

Marsden, C. D. (1984). The pathophysiology of movement disorders. *Neurologic Clinics, 2,* 435-459.

Martin, A.D. (1974). Some objections to the term apraxia of speech. *Journal of Speech and Hearing Disorders, 39,* 53-64.

McCabe, P., Rosenthal, J. B., & McLeod, S. (1998). Features of developmental dyspraxia in the general speech-impaired population? *Clinical Lingusitics and Phonetics, 12, 2,* 105-126.

McCann, J., & Peppe, S. (2003). Prosody in autism spectrum disorders: A critical review. *International Journal of Language and Communication Disorders, 38(4),* 325-350.

McCauley, R. (2003) "What if a child isn't formally diagnosed with Childhood Apraxia of Speech (CAS), but appears to be having motor planning difficulties similar to children who are? *The Apraxia-Kids Monthly, 3* (7), August/September.

McDowell, E. D. (1928). *Educational and emotional adjustment of stuttering children* (NY: Columbia University Teachers College).

Me Neil, M.R., Pratt, S.R., & Fossett, R.D. (2004). *The differential diagnosis of Apraxia of Speech.* In B. Maassen, R. Kent, H.Peters, P.V Leishout & W. Hulstijn, Ed. *Speech motor control in normal and disordered speech,* (pp. 389-414). Oxford University Press, New York, NY.

Melnick, K. S. & Conture, E. G. (2000). Relationship of length and grammatical complexity to the systematic and non-systematic speech errors and stuttering of children who stutter. *Journal of Fluency Disorders, 25, 2*1 - 45.

Milloy, N., & Summers, L. (1989). Six years on- do claims still hold? Four children reassessed on a procedure to identify developmental articulatory dyspraxia. *Child Language Teaching and Therapy, 5,* 287-303.

Miyahara, M., & Mobs, I. (1995). Developmental dyspraxia and developmental coordination disorder. *NeuropsychologicalReview, 5(4)*:245-68.

Miyahara, M., & Register, C. (2000). Perceptions of three terms to describe physical awkwardness in children. *Research in Developmental Disabilities, 21,* 367-376.

Moore, B. C. (2006). *Apraxia: Challenges and Treatment.* Retrieved April 20, 2006 from http://www.nodcc.org/files/Apraxia%20-20Challenges%20&%20Treatments%20-%20by%20Barbara%20C.%20Moore%20MA,%20CCC-SLP.pdf.

Moore, C, & Ruark, J (1996). Does Speech Emerge from Earlier Appearing Oral Motor Behavior? *Journal of 'Speech and Hearing Research. 39,* 1034-1047.

Morley, M. (1957). *The development and disorders of speech in children.* London: Livingstone.

Morley, M. (1965). *The development and disorders of speech in childhood.* Baltimore: Williams & Wilkins

Morley, M.E. (1959). Defects of articulation. *Folia Phoniatrica, 11,* 65-124.

Morrison, J. A. & Shriberg, L. D., (1992), Articulation testing versus conversational speech sampling. *Journal of Speech and Hearing Research, 35,* 259-273.

Mostofsky, S. H., Dubey, PJerath, V. K., Jansiewicz, E. M., Goldbrg, M. C, & Denckl, M. B. (2006). Developmental dyspraxia is not limited to imitation in children with autism spectrum disorders, *Journal of the International Neuropsychological Society,* 72,314-326.

Mostofsky, S., Goldberg, M., Landa, R., & Denckla, M. (2000). Evidence for a deficit in procedural learning in children and adolsescents with autism: implications for cerebellar contribution. *Journal of International Neuropsychological Society. 6,* 752-759.

Murdoch, B., Porter, S., Younger, R. and Ozanne, A. (1984) Behaviours identified by South Australian clinicians as differentially diagnostic of developmental articulatory dyspraxia. *Australian Journal of Human Communication 12 (2)* 55-69.

Nayak, H. M. (1967). *Kannada Literary and Colloquial: A study of two styles.* Mysore: Rao and Raghavan.

Nelson, C. D. (1995). Verbal dyspraxia in treated galactosemia. *Pediatrics, 88,* 346-350.

Nijland, L., Maassen, B., & Meulen, S. (2003). Evidence of motor programming deficits in children diagnosed with DAS. *Journal of Speech, Language, and Hearing Research,* 46, 2, 437-450.

Nijland, L., Maassen, B., van der Meulen, S., Gabreels, F., Kraaimaat, F., & Schreuder, R., (2003). Planning of syllables in children with developmental apraxia of speech. *Clinical Linguistics and Phonetics, 17 (1),* 1-24.

Nijland, L., Maassen, B., Van der Meulen, S., Gabreels, F., Kraaimaat, F. W., & Schreuder, R. (2002). Coarticulation patterns in children with developmental apraxia of speech. *Clinical Linguistics and Phonetics, 16(6), 461-483.*

Nippold, M. A., (1990), Concomitant speech and language disorders in stuttering children: A critique of the literature. *Journal of Speech and Hearing Disorders,* 55,51-60.

Nippold, M. A. (2001). Phonological Disorders and Stuttering in Children: What is the frequency of Co-occurrence?, *Clinical Liguistics and Phonetics, 15 (3),* 219-228

Noterdaeme, M., Mildenberger, K., Minow, F., & Amorosa, H. (2002). Evaluation of neuromotor deficits in children with autism and children with a specific speech and language disorder. *European Child and Adolescent Psychiatry, 11,* 219-225.

Odell, K. H., & Shriberg, L. D. (2001). Prosody-voice characteristics of children and adults with apraxia of speech. *Clinical Linguistics and Phonetics, 15,* 4, 275-307.

Ohta, M. (1987). Cognitive disorders of infantile autism: A study employing the WISC, spatial relationship conceptualization, and gesture imitations. *Journal of Autism and Developmental Disorders, 17,* 45-62.

Ozanne, A. (1995). The search for developmental verbal dyspraxia. In B. Dodd (Ed.), *The differential diagnosis and treatment of children with speech disorder* (pp. 91-109). London: Whurr.

Ozanne, A.E (2005).Childhood apraxia of speech. In B. Dodd (Ed.), *Differential Diagnosis and Treatment of children with Speech Disorders* (pp.71-82). London: Whurr Publishers Ltd.

Paden, E. P. & Yairi, E. (1996). Phonological characteristics of children whose stuttering persisted or recovered. *Journal of Speech and Hearing Research, 39,* 981- 990.

Page, J., & Boucher, J. (1998). Motor impairments in children with autistic disorder. *Child Language Teaching and Therapy, 14,* 233-260.

Panagos, J.M., & Prelock, P.A. (1984). Comments on the interaction of syntactic and phonological disorders. *Journal of Speech and Hearing Research, 27 (2):3*18-20.

Parsons, C. L. (1984). A comparison of phonological processes used by developmentally verbal dyspraxic children and non-dyspraxic phonologically impaired children. *Australian Journal of Human Communication Disorders, 12,* 93-107.

Paul, R., & Shriberg, L.D. (1982). Associations between phonology and syntax in speech-delayed children. *Journal of Speech and Hearing Research, 25 (4) :536-47.*

Pena-brooks, A., & Hegde, M. N. (2000). *Assessment and treatment of articulation and phonological disorders in children.* Austin, TX: Proedinc.

Penhune, V., Zattore, R., & Evans, A. (1998). Cerebellar contributions to motor timing: A PET study of auditory and visual rhythm reproduction. *Journal of Cognitive Neuroscience, 10,* 752-765.

Pollock, K. E. (1994). Assessment and remediation of vowel misarticulations. *Clinics in Communication Disorders,* 4(1), 23-37.

Pollock, K. E., & Hall, P. K. (1991). An analysis of the vowel misarticulations of five children with developmental apraxia of speech. *Clinical Linguistics and Phonetics*, 5, 3, 207-224.

Portwood, M. (2000). *Understanding Developmental Dyspraxia: A Textbook for Students and Professionals.* David Fulton Publishers.

Prizant, B. M. (1996). Brief report: Communication, language, social and emotional development. *Journal of Autism and Developmental Disorders,* 26(2), 1-18.

Prizant, B., Audet, L., Burke, G., Hummel, L., Maher, S., & Theadore, G. (1990). Communication disorders and emotional/behavioral disorders in children and adolescents. *Journal of Speech and Hearing Disorders, 55,*179-192.

Rafaat, S.K., Rvachew, S., & Russell, R.S.C. (1995). Reliability of clinician judgements of severity of phonological impairment. *American Journal of Speech-Language Pathology 4,* 39-46.

Raitano, N. A., Pennington, B. F., Tunick, R. A., Boada, R., & Shriberg, L. D. (2004). Pre-literacy skills of subgroups of children with speech sound disorders. *Journal of Child Psychology and Psychiatry, 45,* 821-835.

Rama Devi, K. J. S. (2006). *Phonological profile in Kannada: A study on hearing impaired.* Unpublished doctoral dissertation, University of Mysore.

Rapin, 1. (1996). Neurological examination. In 1. Rapin & L. Wing (Eds.), *Preschool children with inadequate communication: Developmental language disorder, autism, low IQ.* London, UK: MacKeith Press.

Ratner, B. N. (1998). Linguistic and perceptual characteristicsof children at stuttering onset. In E. C. Healey and H. F. M. Peters (Eds) *Proceedings from the Second World Congress on Fluency Disorders of the International Fluency Association* (Nijmegen, The Netherlands: Nijmegen University Press), 3-6.

Riley, G. D. (1984). Developmental verbal dyspraxia: A clinical perspective. Australian *Journal of Human Communication Disorders, 12,* 83-91.

Robbins, J. A., & Klee, T. (1987). Clinical assessment of oropharyngeal motor development in young children. *Journal of Speech and Hearing Disorders, 52,* 271-277.

Robin, D A. (1992). Developmental Apraxia of Speech: Just another motor problem. *American Journal of Speech-Language Pathology, 1,* 19-22.

Robin, D.A. (2003). "Childhood Apraxia of Speech: Assessment, Treatment & Current Issues", a Hendrix Foundation/CASANA workshop presented in San Diego, CA.

Rogers, S. J., Bennetto, L., McEvoy, R., & Pennington, B. F. (1996). Imitation and pantomime in high functioning adolescents with autism spectrum disorders. *Child Development, 67,* 2060-2073.

Rogers, S.J., Hepburn, S.L., Stackhouse, T., & Wehner, E. (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Journal of Child Psychology and Psychiatry, 44,* 763-781.

Rogers-Adkinson, D., & Griffith, P. (1998). *Communication and psychiatric disorders in children.* San Diego, CA: Singular.

Rosenbek, J.C & Wertz, R.T. (1972). A review of 50 cases of developmental apraxia of speech. *Language Speech and Hearing Services in Schools,* 5:23-33.

Rosin, M. M., Swift, E., Bless, D., & Vetter, D. K. (1988). Communication profiles of adolescents with Down syndrome. *Journal of Childhood Communication Disorders, 12,* 49-64.

Rupela, V. & Manjula, R. (2006). Phonotactic development in Kannada: some aspects and future directions. *Language Forum: A Journal of Language and Literature, 32* (1-2), 83-93.

Rvachew, S., Ohberg, A., Grawburg, M., & Heyding, J. (2003). Phonological awareness and phonemic perception in 4-year-old children with delayed expressive phonology skills. *American Journal of Speech-Language Pathology, 12,* 463^471.

Saddock, B. J., & Saddock, V. A. (2005). *Comprehensive Textbook of Psychiatry.* Lippincott, Williams & Williams, Philadelphia.

Schindler, M. A. (1955). A study of educational adjustments of stuttering and nonstuttering children. In W. Johnson and R. Leutenegger (Eds), *Stuttering in children and adults* (Minneapolis: University of Minnesota Press), pp. 348 - 357.

Schoemaker, M. M., van der Wees, M., Flapper, B., et al. (2001). Perceptual skills of children with developmental coordination disorder. *Human Movement and Sciences, 20* (1-2), 111-133.

Schumacher, J.G., McNeil, M.R., Vetter, D.K., & Yoder, D.E. (1986). Articulatory *consistency and variability in apraxic and non-apraxic children.* Paper presented at the American Speech and Hearing Association Convention, (Detroit, MI). In P. Hall, L. Jordan, & D. Robin, (1993). *Developmental Apraxia of Speech: Theory and Clinical Practice.* Austin, TX, Pro-Ed.

Schwartz, R. (1992). Clinical applications of recent advances in phonological theory. Language, Speech, and Hearing Services in Schools, 23, 269 - 276.

Schwartz, R., & Leonard, L. (1983). Some further comments on reduplication in child phonology, *Journal ofChild Language, 10(2),* 441-448.

Schwartz, R.., Leonard, L., Wilcox, M., & Folger, M. (1980). Again and gain: Reduplication in child phonology. *Journal of Child Language, 7,* 75-87.

Seal, B. C, & Bonvillian, J. D. (1997). Sign language and motor functioning in students with autistic disorder. *Journal of Autism and Developmental Disorders, 27(4),* 437-466.

Seider, R. A., Gladstien, K. L. & Kidd, K. K. (1982). Language onset and concomitant speech and language problems in subgroups of stutterers and their siblings. *Journal of Speech and Hearing Research,* 25, 482 - 486.

Shattuck-Huffnagle, S. (1983). Sublexical units and suprasegmental structure in speech production planning. In P. F. MacNeilage (Ed.) *The production of speech* (New York, NY: Springer), pp. 109 - 136.

Sheinkopf, S. J., Mundy, P., Oiler, D. K., & Steffens, M. (2000). Vocal atypicalities of preverbal autistic children. *Journal of Autism and Developmental Disorders, 10(4),* 345-354.

Shelton, R. L., & McReynolds, L. V. (1979). Functional articulation disorders. In N. J. Lass (Ed.): *Speech and Language-Advances in Basic Research and Practice.* Academic Press, New York (pp 82-88).

Shipley, K., & McAfee, J. (1998). *Assessment in speech-lanugage pathology: A resource manual* (2nd ed.). San Diego: Singular Publishing Group.

Shoemaker, M. M., Hijlkema, M. G., & Kalverboer, A. F. (1994). Physiotherapy for clumsy children: an evaluation study. *Developmental Medicine and Child Neurology, 36,* 143-155.

Shriberg, L. D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech, Language and Hearing Research, 36,* 105-140.

Shriberg, L. D. (1997). Developmental phonological disorders: one or many? In B. W. Hodson and M. L. Edwards (Eds.), *Perspectives in Applied Phonology* (Gaithersburg, MD: Aspen), 105-127.

Shriberg, L. D., Aram, D. M., & Kwiatkowski, J. (1997a) Developmental Apraxia of Speech: I. Descriptive and Theoretical Perspectives. *Journal of Speech and Hearing Research, 40 (2),* 254-272.

Shriberg, L. D., Aram, D. M., & Kwiatkowski, J. (1997b). Developmental Apraxia of Speech: II. Toward a diagnostic marker. *Journal of Speech and Hearing Research, 40 (2),* 254-272.

Shriberg, L. D., Aram, D. M., & Kwiatkowski, J. (1997c). Developmental Apraxia of Speech: III. A Subtype marked by inappropriate stress. *Journal of Speech and Hearing Research, 40 (2),* 254-272.

Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., & Wilson, D. L. (1997). The Percentage of Consonants Correct (PCC) metric: Extensions and reliability data. *Journal of Speech, Language, and Hearing Research, 40(4),* 708-722.

Shriberg, L. D., Campbell, T. F., Karlsson, H. B., Brown, R. L., McSweeny, J. L., & Nadler, C. J. (2003a). A diagnostic marker for childhood apraxia of speech: The lexical stress ratio. *Clinical Linguistics and Phonetics, 17,* 549-574.

Shriberg, L. D., Green, J. R., Campbell, T. F., McSweeny, J. L., & Scheer, A. (2003b). A diagnostic marker for childhood apraxia of speech: The coefficient of variation ratio. *Clinical Linguistics and Phonetics, 17,* 575-595.

Shriberg, L. D., Hosom, J.-P., & Green, J. R. (2004). *Diagnostic assessment of childhood apraxia of speech using Automatic Speech Recognition (ASR) systems.* Paper presented at the 2004 Speech Motor Control Conference, Albuquerque, NM.

Shriberg, L. D., Paul, R., McSweeny, J. L., Klin, A., Volkmar, F. R., & Cohen, D. J. (2001). Speech and prosody characteristics of adolescents and adults with High Functioning Autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research, 44,* 1097-1115.

Shriberg, L. & Kwiatkowski, J. (1980). *Natural Process Analysis: A Program for Phonological Analysis of Continuous Speech Samples.* New York: John Wiley & Sons.

Shriberg, L. D., & Kwiatkowski, J. (1982) Phonological disorders II. A procedure for assessing severity of involvement. *Journal of Speech and Hearing Disorders, 47,* 256-270.

Shriberg, L. D., & Kwiatkowski, J. (1988). A follow-up study of children with phonologic disorders of unknown origin. *Journal of Speech and Hearing Disorders, 53,* 144-155.

Shriberg, L. D., & McSweeny, J. L. (2002). *Classification and misclassification of childhood apraxia of speech* (Tech. Rep. No. 11). Madison: Phonology Project, Waisman Center, University of Wisconsin.

Shriberg, L. D., & Widder, C. J. (1990). Speech and prosody characteristics of adults with mental retardation. *Journal of Speech and Hearing Research, 33,* 627-653.

Shyamala, K. C, & Basanti, D. (2003). *Developmental Milestones of Language Acquisition in Indian Languages: Kannada and Hindi.* Unpublished manuscript, University of Mysore.

Smit, A. B. (2004). *Articulation and Phonology Resource Guide for School-Age Children and Adults.* Manhattan, Kansas: Thomson Delmar Learning.

Smith, A., Goffman, L., & Stark, R. E. (1995). Speech Motor Development. *Seminars in Speech and Language, 16, SI-99.*

Smith, B. L., & Stoel-Gammon, C. (1983). A longitudinal study of the development of stop consonant production in normal and Down's syndrome children. *Journal of Speech and Hearing Disorders, 48,* 114-118.

Smith, B., Marquardt, T. P., Cannito, M. P., & Davis, B. L., (1994). Vowel variability in Developmental apraxia of speech. In J. A. Till, K.M. Yorkston, & D. R. Beukelman (Eds.). *Motor speech disorders: Advances in assessment and treatment* (pp. 81-89). Baltimore, MD: Paul H. Brookes Publishing Co.

Smith, I., M. (2000). Motor functioning in Asperger syndrome. In A. Klin, F. R. Volkmar & S. S. Sparrow (Eds.), *Asperger syndrome.* New York: Guildord Press.

Smith, I., M., & Bryson, S. E. (1994). Imitation and action in autism: A critical review. *Psychological Bulletin, 116,* 259-273.

Smith, M.D., & Damico, J.S. (1995). *Childhood language disorders: Current therapy of communication disorders.* New York: Thieme.

Smits-Engelsman, B. C, Niemeijer, A. S., van Galen, G. P. (2001). Fine motor deficiencies in children diagnosed as DCD based on poor graphomotor ability. *Human Movement and Sciences, 20(* 1 -2): 161 -182.

Smyth, T. R. (1992). Impaired motor skill (clumsiness) in otherwise normal children: a review. *Child Care, Health, and Development, 18,* 283-300.

Smyth, M. M., & Mason, U. C. (1997). Planning and execution of action in children with and without developmental coordination disorder. . *Journal of Child Psychology and Psychiatry, 38,* 1023-1037.

Snowling, M, & Stackhouse, J. (1983). Spelling performance of children with Developmental Verbal Dyspraxia. *Developmental Medicine and Child Neurology, 25,* 430-437.

Snowling, M.J., Goulandris, N., & Stackhouse, J. (1994). Phonological constraints on learning to read: evidence from single-case studies of reading difficulty. In Hulme, C. & Snowling, M.J. (Eds) *Reading development and dyslexia.* London : Whurr Publishers. 86-104.

Sommers, R. K., Patterson, J. P., & Wildgen, P. L. (1988). Phonology of Down syndrome speakers, ages 13-22. *Journal of Childhood Communication Disorders, 12* (1), 65-91.

Square, P.A. (1999). Treatment of Developmental apraxia of speech: Tactile - Kinesthetic, rhythmic, and gestural approaches. In A. Caruso & E.Strand (Eds) *Clinical Management of Motor Speech Disorders in Children.* (P. 149-186). Thieme, New York.

Square-Storer, P. A., Darley, F. L., & Sommers, R. K. (1988). Speech processing abilities in patients with aphasia and apraxia of speech. *Brain and Language, 33,* 65-85.

St Louis, K. O. & Hinzman, A. R., (1988). A descriptive study of speech, language, and hearing characteristics of school-aged stutterers. *Journal of Fluency Disorders,* 57,331 -355.

St Louis, K. O., Murray, C. D. & Ashworth, M. S. (1991). Coexisting communication disorders in a random sample of school-aged stutterers. *Journal of Fluency Disorders,* 16, 13-23.

Stackhouse, J. (1992). Developmental verbal dyspraxia I: A review and critique. *European Journal of Disorders of Communication,* 27, 19-34.

Stackhouse, J., & Snowling, M. (1992). Developmental verbal dyspraxia. II: A developmental perspective on two case studies. *European Journal of Disorders of Communication, 27,* 35-54.

Stark, R. (1985). *Dysarthria in children.* In J.Darby (Ed.) Speech and Language evaluation in Neurology: Childhood Disorders (pp. 185-217). Orlando, FL: Grune & Stratton.

Stoel-Gammon, C. (1980). Phonological analysis of four Down's syndrome children. *Applied Psycholinguistics, 1,* 31-48.

Stoel-Gammon, C. (1997). Phonological development in Down syndrome. *Mental Retardation and Developmental Disabilities Research Reviews, 3,* 300-306.

Stoel-Gammon, C. (2001). Down syndrome phonology: Developmental patterns and intervention strategies. *Down syndrome: Research and Practice,* 7(3), 93-100. Retrieved February 14, 2005 from http://www.down-syndrome.net/library/ "periodicals/dsrp/07/03/C

Stoel-Gammon, C, & Cooper, J. A. (1984). Patterns of early lexical and phonological development. *Journal of Child Language, 11,* 247-271.

Stoel-Gammon, C, & Dunn, C. (1985). *Normal and abnormal phonology in children.* Austin Texas: Pro-Ed. Inc.

Strand, E. A. (1997). *Oral motor function assessment.* Unpublished assessment protocol.

Strand, E. (2002). *Childhood apraxia of speech: suggested diagnostic markers for the younger child.* Childhood Apraxia of Speech Research Symposium, Phoenix, AZ.

Strand, E. A. (2003). Childhood apraxia of speech: suggested diagnostic markers for the young child. In L.D. Shriberg, and T. F. Campbell, (Eds) *Proceedings of the 2002 childhood apraxia of speech research symposium.* Carlsbad, CA: Hendrix Foundation. Retrieved from http://www.apraxia-kids.org/site/apps/nl/content3.

Strand, E. A., & McCauley, R. J. (2000). *Differential diagnosis of severe articulatory impairment in children.* Presented at the annual convention of the American-Speech Language and Hearing Association, November, Washington D.C.

Studdert-Kennedy, M., & Goodell, E. W. (1992). Gestures, features, and segments in early child speech. *Huskins Laboratories Status Report on Speech Research , SR-111/112,* 1-14.

Sussman, H. M., Marquardt, T. P., & Doyle, J. (2000). An acoustic analysis of phonemic integrity and contrastiveness in developmental apraxia of speech. *Journal of Medical Speech-Language Pathology, 8(4),* 301-313.

Tetnowski, J. A., 1998, Linguistic effects on disfluency. In R. Paul (Ed.), *Exploring the speech-language connection* (Baltimore: Brookes), 227- 251.

Thoonen, G., Maassen, B., Gabreels, F., & Schreuder, R. (1994). Feature analysis of singleton consonant errors in developmental verbal dyspraxia (DVD). *Journal of Speech and Hearing Research, 37(6),* 1424-40.

Thoonen, G., Maassen, B., Wit, J., Gabreels, F., & Schreuder, R. (1996). The integrated use of maximum performance tasks in differential diagnostic evaluations among children with motor speech disorders. *Clinical Linguistics and Phonetics, 10(4),* 311-336.

Thoonen, G, Maassen, B, Gabreels, F, Schreuder, R, & de Swart, B. (1997). Towards a standardised assessment procedure for developmental apraxia of speech. *European Journal of Communication Disorders, 32(1),* 37-60.

Thoonen, G., Maassen, B., Gabreels, R, & Schreuder, R. (1999). Validity of maximum performance tasks to diagnose motor speech disorders in children. *Clinical Linguistics and Phonetics, 13,* 1-23.

Tyler, A. A., Lewis, K. E., & Welch, C. M. (2003). Predictors of phonological change following intervention. *American Journal of Speech-Language Pathology, 12,* 289-298.

Upadhyaya, U. P. (1972). *Kannada Phonetic Reader.* Mysore: CIIL Publications.

Van Borsel, J. (1988). An analysis of the speech of five Down's syndrome adolescents. *Journal of Communication Disorders, 21(5),* 409-421.

Van Borsel, J. (1996). Articulation in Down syndrome adolescents and adults. *European Journal of Disorders of Communication, 31,* 415-444.

Van der Merwe, A. (1997). A theoretical framework for the characterization of pathological speech sensorimotor control. In M.R. McNeil, (Ed.) *Clinical Management of sensorimotor speech disorders,* pp. 1-25. Thieme, New York

Velleman, S. L. (1994). The interaction of phonetics and phonology in developmental verbal dyspraxia: two case studies. *Clinics in Communication Disorders, 4 (1),* 66-77.

Velleman, S. L. (1996). The development of phonology and mental representations in a child with pervasive developmental disorder. In T. P. Powell (Ed.), *Pathologies of Speech and Language: Contributions of Clinical Phonetics and Linguistics* (pp. 27-36). New Orleans, LA: International Clinical Phonetics and Linguistics Association.

Velleman, S. L. (1998). *Making Phonology Functional.* Boston: Butterworth-Heinemann.

Velleman, S. (2002). Phonotactic therapy. *Seminars in Speech and Language, 23,* 43-57.

Velleman, S. L. (2003). *Resource guide for Childhood Apraxia of Speech.* Clifton Park, NY: Delmar/Thomson Learning.

Velleman, S. & Strand, K. (1994). *Developmental Verbal Dyspraxia.* In J. Bernathal (Ed). Phonological characteristics of special Populations. New York: Thieme Medical Publishers.

Velleman, S. L., & Shriberg, L. D. (1999). Metrical analysis of the speech of children with suspected developmental apraxia of speech. *Journal of Speech, Language and Hearing Research, 42,* 1444-1460.

Velleman, S.L., & Strand, K. (1995). *Assessment and treatment of developmental verbal dyspraxia: A new perspective.* Division of continuing studies communication programs, University of Wisconsin- Madison. Retrieved May 10, 2005 from http://www.apraxia-kids.org/library/html

Velleman, S. L. & Vihman, M. M. (2002). Whole word phonology and templates: Traps, bootstrap or some of each? *Language, Speech and Hearing Services in the Schools, 33,* 9-23.

Venkatesan, S. (2003). *Toy kit for kids with developmental disabilities.* Mysore: AIISH.

Vihman, M., Ferguson, C, & Elbert, M. (1986). Phonological development from babbling to speech: Common tendencies and individual differences. *Applied Psycholinguistics, 7,* 31-40.

Vihman, M. M., & Velleman, S. L. (1989). Phonological reorganization: A case study. *Language and Speech, 32,* 149-170.

Vihman, M. M., Velleman, S. L., & McCune, L. (1994). How abstract is child phonology? Towards n integration of linguistic and psychological approaches. InM. Yavas (Ed.), *First and second language phonology* (pp. 9-44). San Diego, CA: Singular Press.

Walton, J., Ellis, E., & Court, S. (1962). Clumsy children: Developmental apraxia of agnosia. *Brain, 85,* 603-612.

Watkins, K. E., Dronkers, N. F., & Vargha-Khadem, F. (2002). Behavioral analysis of an inherited speech and language disorder: Comparison with acquired aphasia. *Brain, 125,* 452-462.

Weismer, G. (1997) Motor speech disorders, In Hardcastle, Laver, *Handbook of phonetic sciences*, pp. 191-219 (Blackwell, Oxford).

Weistuch, L., & Myers, N. B. (1996). Chromosomal translocation in a child with SLI and apraxia. *Journal of Speech and Hearing Research, 39,* 6681671.

Wetherby, A., Yonclas, D., & Bryan, A. (1989). Communicative profiles of handicapped preschool children: Implications for early identification. *Journal of Speech and Hearing Disorders, 54,* 148-158.

Whitebread, S., Dvorak, C, & Jakielski, K. (1999). *"Treatment Effects on Speech Intelligibility in Developmental Apraxia of Speech,"* Presentation at the American Speech-Language-Hearing Association., November, Austin, TX.

Whiteside, S.P & Varley, R.A. (1998). A Reconceptualisation of Apraxia of Speech: A Synthesis of Evidence. *Cortex, 34,* 221-231.

Williams, M. A. (1988). *"Developmental Apraxia".* Communication Skill Builders. Inc. Retrieved June 10, 2007 from http://www.wyandotte.org/SpecialEd/apraxia.htm.

Williams, R., Ingham, R. J., & Rosenthal, J. (1981). A further analysis for developmental apraxia of speech in children with defective articulation. *Journal of Speech and Hearing Research, 24,* 496-506.

Williams, D. E. & Silverman, F. H., (1968), Note concerning articulation of school-age stutterers. *Perceptual and Motor Skills, 27,* 713- 714.

Williams, J.H., Whiten, A., & Singh, T. (2004).Asystematic review of action imitation in autistic spectrum disorder. *Journal of Autism and Developmental Disorders, 34,* 285-299.

Wilson, P. H., Maruff, P., Ives, S., & Currie, J. (2001) Abnormalities of motor and praxis imagery in children with DCD. *Human Movement and Sciences, 20(1-2):* 135-159.

Wolk, L. (1998). Intervention strategies for children who exhibit coexisting phonological and fluency disorders: A clinical note. *Child Language Teaching and Therapy, 14, 69-* 82.

Wolk, L., & Edwards, M. L. (1993). The emerging phonological system of an autistic child. *Journal of Communication Disorders, 26,* 161-177.

Wolk, L., & Giesen, J. (2000). A phonological investigation of four siblings with childhood autism. *Journal of Communication Disorders, 33,* 371-389.

Wolk, L., Edwards, M. L. & Conture, E. G. (1993). Coexistence of stuttering and disordered phonology in young children. *Journal of Speech and Hearing Research, 36,* 906-917.

Yairi, E. (1981). Dysfluencies of normally speaking two-year old children. *Journal of Speech and Hearing Research, 24,* 490-495.

Yaruss, J. S. & Conture, E. G.(1996). Stuttering and phonological disorders in children: Examination of the covert repair hypothesis. *Journal of Speech and Hearing Research, 39,* 349- 364.

Yaruss, J. S., LaSalle, L. R. & Conture, E. G. (1998). Evaluating stuttering in young children: Diagnostic data. *American Journal of Speech-LanguagePathology, 7, 2*-76.

Yoss, K. A., & Darley, F. L. (1974). Developmental apraxia of speech in children with defective articulation. *Journal of Speech and Hearing Research, 17,* 399-416.

Zeigler, W. & Von Cramon, D. (1985). Anticipatory coarticulation in a patient with apraxia of speech. *Brain and Language, 26,* 117-130.

Zeigler, W. & Von Cramon, D. (1986a). Disturbed coarticulation in apraxia of speech: acoustic evidence. *Brain and Language, 29,* 34-47.

Zeigler, W. & Von Cramon, D. (1986b). Timing deficits in apraxia of speech. *European Archives of Psychiatry and Neurological Sciences, 236, AA-49.*

Zisk, P. K., & Bialer, I. (1976). Speech and language problems in mongolism. *Journal of Speech and Hearing Disorders, 32,* 228-241.

Appendices

APPENDIX I

SCREENING CHECKLIST

Name of the child :

Date of Evaluation:

Date of Birth :

Age :

Gender ;

Primary Diagnosis :

An overview of child's verbal behavior in as much detail as possible.

SCREENING CHECKLIST

Note: Information with respect to items 1 to 10 to be obtained from parent of the child. The rest of the items are to be scored by the Speech Language Pathologist. The items are to be recorded as 'Yes' or 'No' (Score 1 is offered for 'Yes' and 0 for 'No').

SNo.	Information from Parents	Yes /No
1	Is there any family history of speech, language, hearing or learning deficits?	
2	*Psycho social history:* Does your child show high frustration levels, behavioural problems, and excessive shyness especially in unfamiliar social settings?	
3	*History of feeding:* a) Does your child show poor coordination of suck-swallow-breathe process resulting in mild but frequent coughing / choking or spillage? b) Does your child exhibit excessive drooling, especially when talking or engaged in other motor activities?	
4	Was your child a quiet baby, that is, he / she did not show much of vocalization / verbalizations especially between 4-12 months of age?	
5	*Prebabble vocalizations:* Did your child present the following: a) There was no or little babbling except vowel like vocalizations? b) The babble consisted of few or no consonants?	
6	*Intelligibility:* Did the intelligibility of speech of your child vary from situation to situation? E.g. speech was more intelligible with closest family members when compared to that with strangers	
7	*Rate of Speech:* Does your child use a slow rate of speech?	
8	*Development of Speech:* Did the child show delayed development of speech (i.e., the development of speech occurred at a slower rate when compared with his / her counterparts?	
9	*Use of non-verbal modes:* Did your child show increased use of gestures to communicate his needs (For e.g. leading parents to desired objects)? Or use mime, conventional or idio-syncratic signs (natural gesture system invented by child) or both?	
10	*Play:* Did your child exhibit age-appropriate, single action pretend play, but showed delay in developing sequences of pretend play?	

SNo.	Observations by the Speech Language Pathologist	Yes /No
11	Are there any indications of soft neurological signs (immature reflexes, mild low muscle tone, sensory hypersensitivity, or hyposensitivity)?	
12	Does the child show difficulty in voluntary use of oral structures?	
13	Does the child have difficulty in moving the tongue independently of jaw?	
14	Does the child show any evident silent posturing / Groping (searching for articulators) or effort at initiation of speech?	
15	Does the child show difficulty in learning sequenced movements (E.g., learning sequenced speech movements to utter a particular word)?	
16	Does the child show incoordination while shifting from one motor activity to another?	
17	Does the child experience difficulty with initial consonants in words?	
18	Does the child omit or distort vowel sounds?	
19	Does the child show word or morpheme sequencing errors (e.g., "he's go" for "he goes")?	
20	Does the child tend to produce a word once and never utter the same word again in a same or different context? In other words, are the responses of the child inconsistent?	
21	Does the child demonstrate multiple inconsistent misarticulations?	
22	Does the child produce some words involuntarily and is unable to reproduce or imitate the same on request?	
23	Does the child demonstrate prolongations and syllable additions in speech frequently?	
24	Does the child repeat sounds and syllables in multi syllabic words?	
25	Does the child transpose sounds within words (E.g., naba:na / bana:na)?	
26	Does the child use more of signs / gestures, vocal noises, and / or idiosyncratic words than meaningful intelligible words?	
27	Does the child use signs and gestures along with a few words while attempting to speak in sentences?	
28	Does the child omit, mis-select or mis-place pronouns (e.g., adu - meaning 'that / it', ava\u - meaning 'she', na:nu - meaning T) and PNG markers (structures referring to person, number and gender)?	
29	Does the child exhibit difficulty in organizing and sequencing segments (speech sounds) while speaking or when indulged in conversations?	
30	Does the child show poor accuracy for words as and when the length or phonetic complexity of the utterance increases?	
31	Does the child show poor accuracy for words which increase the conceptual or syntactic load of the utterance?	

I. ORAL MOTOR ASSESSMENT

A. ORAL STRUCTURES AT REST

Score 2 for 'a', 1 for 'b' and 0 for 'c'.

1. The child's jaw is:
a) In normal alignment
b) Slightly protracted or retracted
c) Noticeably protracted or retracted

2. The child's jaw at rest is:
a) Closed
b) Slightly open
c) Noticeably open

3. The child's lips are:
a) In a normal position
b) Slightly protruded or retracted
c) Obviously protruded or retracted

4. The child
a) Does not drool
b) Drools, but tries to swallow it
c) Drools and does not use any strategy to clear it

5. The child's tongue is:
a) Placed appropriately inside the mouth
b) On the bottom of the lower lip
c) Outside the mouth

6. Based on the interpretation from the five items above, the oral structures seems to show
a) Normal tone
b) Mildly abnormal tone
c) Moderately abnormal tone

7. Involuntary movements are:
a) Absent
b) Present but barely noticeable
c) Apparently present

8. When the child moves his/her oral structures:
a) Other parts of the body do not move
b) Other parts of the body move minimally
c) Other parts of the body move noticeably (and hinder in speech production)

B. FUNCTION OF THE ORAL MECHANISM FOR SPEECH

Score 1 for 'adequate' and 0 for 'inadequate'

1. The intra-oral air build-up for stops is Adequate/Inadequate
2. Air build up and precision of fricatives is Adequate/Inadequate
3. Oral-nasal distinction is Adequate/Inadequate

The following activities have to be observed without asking the child to imitate or do these activities:

4. When the child spreads his lips, the range of movement of lips is Adequate/Inadequate
5. When the child opens and closes his/her mouth, range of movement of jaw is Adequate/Inadequate
6. When the child moves the tongue from side to side, the range of movement is Adequate/Inadequate

II. ORAL PRAXIS ASSESSMENT

A. ISOLATED ORAL MOVEMENTS

The child is asked to imitate the following movements.

Action	*Accuracy*	*Rate*	*Repetitions*	*Score*
Jaw movement				
1. Click teeth together once				
2. Open your mouth				
3. Close your mouth				
4. Hold your mouth open at midrange				
Lip movement				
5. Smile				
6. Pucker lips				
7. Bite lower lip				
8. Blow				
9. Pretend to kiss				
Tongue movement				
10. Stick out your tongue				
11. Lick your lips with tongue				
12. Touch the nose with tip of tongue				
13. Move your tongue in and out				
14. Move your tongue to the right				
15. Move your tongue to the left				
16. Click your tongue				
17. Wiggle your tongue from side to side				

Others				
18. Clear your throat				
19. Puff up your cheeks				

The accuracy and rate are evaluated based on the number of repetitions provided. All responses are scored based on rate, accuracy and cues used as follows:

4- Movement/action is accurate and rate is appropriate
3- Movement/action is accurate and rate is appropriate with one repetition
2- Either movement/action or rate is inappropriate with more than one repetition
1- Both are inappropriate with more than one repetition
0- Child is unable to perform even with repetitions

B. SEQUENTIAL ORAL MOVEMENTS

The child is asked to imitate the following sequential oral movements:

SNo.	Stimulus	Response	MCS	SMS
1	Bite and blow			
2	Smile and kiss			
3	Blow and smile			
4	Kiss and stick out your tongue			
5	Bite and open your mouth			

Two types of scores are given as follows:

Motor control score (MCS):
2- Both movements are precise
1- One of the movements is imprecise
0- Both movements are imprecise

Sequence maintenance score (SMS):
2- Completes both movements in the order stated (correct sequence)
1- Completes both movements in reverse order (incorrect sequence) or adds an extra movement
0- Completes only one movement or completes the same movement twice

III. VERBAL PRAXIS ASSESSMENT

A. **ISOLATED VERBAL MOVEMENTS**

The child is asked to imitate the following syllables, consonants and vowels.

Action	*Accuracy*	*Repetitions*	*Score*
Jaw movement			
1. Open your mouth and say ‘ahh’			
2. Close your mouth and say ‘m…’			
3. Say /jə/			
4. Say /əi/			
5. Say /əu/			
Lip movement			
6. Say /pə/,			
7. Say /o/			
8. Say /u/			
9. Say /i/			
10. Say /e/			

Action		*Repetitions*	*Score*
Tongue movement			
11. Say/fa/,			
12. Say/da/,			
13. Say'n…'			
14. Say i…'			
15. Say's…'			
16. Say/ks/,			
17. Say/g9/			
18.Say/ta/,			
19. Say/(la/			
20. Say/tf3/			
21. Say/ft/			
22. Say'shh...'			

The speech movements are scored based on rate, accuracy and cues used as follows:

3- Movement/action is accurate
2- Movement/action is accurate with one repetition
1 - Movement/action is inappropriate with more than one repetition
O-Child is unable to perform even with repetitions

B. SEQUENTIAL VERBAL MOVEMENTS

The child is asked to imitate the following sequential verbal utterances:

SNo.	Stimulus	Transcribed response	MCS	SMS
1	a-u			
2	o-i			
3	m-u			
4	a-m-u			
5	u-i-a			
6	i-u-a			
7	m-o-i			

Two types of scores are given as follows:

Motor control score (MCS):
2- All movements are precise
1- One of the movements is imprecise
0- All movements are imprecise or child substitutes one phoneme for another or child does not say all phonemes

Sequence maintenance score (SMS):
2- Repeats all phonemes correctly
1- Repeats 2 out of 3 oromotor sequences correctly or repeats the oromotor phonemes 5 or 6 times
0- Repeats one out of 3 oromotor sequences correctly or repeats the oromotor phoneme sequence more than 6 times

If the child does not respond, write NR next to the column

C. WORD LEVEL PRAXIS ASSESSMENT

The child is asked to repeat the following words after the investigator.

Target	*Transcribed response*	*Phonological Errors*			*Groping*	*Dysfluencies*	*Weak precision*	*SMS*
		SE	TE	WWE				
tale								
si:re								
məne								
se:bu								
na:ji								
bekku								
pennu								
tʃ^{h}ətri								
təʈʈe								
su:rja								
ba:gilu								
huɖugi								
kiʈəki								
tʃəmətʃa								
kudəlu								
ba:gilu								
da:ɭimbe								
pustəka								
tʃəppəli								
i:ruɭɭi								
ərəməne								
əɖigeməne								
ba:tʃəɳige								
gəɖija:ra								
ga:ɭipəʈa								
kənnəɖəka								
ba:ɭehəɳɳu								
de:vəst^{h}a:na								
a:lu:gəɖɖe								
teŋginəka:ji								
kriʃɳa								
driʃja								

Target	*Transcribed response*	*Phonological Errors*			*Groping*	*Dysfluencies*	*Weak precision*	*SMS*
		SE	TE	WWE				
prəʃne								
swətʃtʃʰa								
vaidja								
vjəvəstʰe								
pra:tʰəmika								
brəmhərʃi								
svərgəstʰa								
prəkʃubdʰa								
Total scores								

The errors are transcribed and total number of errors is counted. A score of 1' is given for each error.

Key for scoring errors:

Space errors (SE): fronting, backing, palatalisation, depalatalisation; and vowel deviations including vowel prolongation, vowel shortening, vowel centralization, vowel decentralization, monophthongization, diphthongization, vowel raising and vowel lowering.

Timing errors (TE): voicing errors, affrication, deaffrication, denasalization, gemination and degemination of consonants.

Whole word errors (WWE): cluster reduction, reduplication, consonant harmony, migration, metathesis, epenthesis, initial consonant deletion, medial consonant deletion, initial, medial and final syllable deletions

Groping errors: Self-corrections or change of position of articulators- silent groping. False starts-audible groping

Dysfluencies: repetitive production of speech sounds, hesitations, pauses

Weak precision: when there is weak approximation of active articulator with passive articulator.

Sequence maintenance score (SMS): Disyllabic words

2- Repeats both syllables in the correct order
1- Repeats both syllables in reverse order or repeats a syllable or adds/deletes a syllable
0- Repeats only one syllable or does not repeat any syllable

If the child does not respond, mark NR and score 0

Sequence maintenance score: Trisyllabic and multisyllabic words

2- Repeats all syllables in the correct sequence
1- Repeats all syllables except one in the correct sequence or any one syllable in reverse order or addition/deletion of a syllable
0- Repeats one syllable correctly or does not repeat any syllable in the correct order

If the child does not respond, mark NR (No response) and score 0

Note: Do not penalize the child for consonant/vowel substitution unless where consonant/vowel harmony and cluster reduction occurs as repetition of syllables takes place

D. SENTENCE LEVEL ASSESSMENT

The child is asked to repeat the following sentences after the investigator.

Target	Transcribed response	SMS
illi ba		
ədu məra		
na:n bərijəlla		
nənge ʤvəra idɛ		
a karu hogta idɛ		
sku:ləlli ʧənna:g o:dbeku		
məisu:rəlli ərməne idɛ		
gaɭipəʈa məgu kəijəllidɛ		
nəməɳɳa ka:fi kuɖita iddare		
nenne əmma nənge məisur pa:k ma:ɖkoʈru		

The following calculations are done:

$$\textbf{PCC} = \frac{\text{Total number of consonants produced correctly}}{\text{Total number of consonants attempted}} \times 100$$

$$\text{PVC} = \frac{\text{Total number of vowels produced correctly}}{\text{Total number of vowels attempted}} \times 100$$

Sequence maintenance score:

2- All the words are in the exact order or position

1- Sentences with < 3 words- At least 1 word is in order
Sentences with > 3 words-At least 3 of the key words are in order

0- Sentences with < 3 words- 0 words in order
Sentences with > 3 words- 2, 1 or no key words are in order

E. ANALYSIS OF SPONTANEOUS SPEECH SAMPLE

A conversational speech sample of around 100 words is recorded by asking the child general questions about his name, friends, family, house, school etc.

Transcribed sample:

The following calculations were done:

'Percentage of Consonants Correct' (PCC) is calculated using the formula:

$$\textbf{PCC} = \frac{\text{Total number of consonants produced correctly}}{\text{Total number of consonants attempted}} \times 100$$

The total number of vowel errors is tallied from the transcribed samples and the percentage of vowels correct (PVC) is calculated as follows:

$$\textbf{PVC} = \frac{\text{Total number of vowels produced correctly}}{\text{Total number of vowels attempted}} \times 100$$

Phonotactic analysis: Calculate the different types of syllables (V, CV, VC, CVC), words (mono-, di-, tri-, multi-syllabic) and clusters (initial, medial geminate, medial non-geminate, medial three-sound, final) from the words to calculate their percentage occurrences.

Percentage occurrences of different types of syllables

$$\frac{\text{Number of V syllables}}{\text{Total number of syllables}} \times 100 = \%\ \text{V syllables}$$

$$\frac{\text{Number of CV syllables}}{\text{Total number of syllables}} \times 100 = \%\ \text{CV syllables}$$

$$\frac{\text{Number of VC syllables}}{\text{Total number of syllables}} \times 100 = \%\ \text{VC syllables}$$

$$\frac{\text{Number of CVC syllables}}{\text{Total number of syllables}} \times 100 = \%\ \text{CVC syllables}$$

Percentage occurrences of different types of words

$$\frac{\text{Number of monosyllabic words}}{\text{Total number of words}} \times 100 — \%\ \text{monosyllabic words}$$

$$\frac{\text{Number of disyllabic words}}{\text{Total number of words}} \times 100 = \%\ \text{disyllabic words}$$

$$\frac{\text{Number of trisyllabic words}}{\text{Total number of words}} \times 100 = \%\ \text{trisyllabic words}$$

$$\frac{\text{Number of multisyllabic words}}{\text{Total number of words}} \times 100 = \%\ \text{multisyllabic words}$$

Percentage occurrences of different types of clusters

$$\frac{\text{Number of initial clusters}}{\text{Total number of words}} \times 100 = \%\ \text{initial clusters}$$

$$\frac{\text{Number of medial geminate clusters}}{\text{Total number of words}} \times 100 = \%\ \text{medial geminate clusters}$$

$$\frac{\text{Number of medial non-geminate clusters}}{\text{Total number of words}} \times 100 = \%\ \text{medial non-geminate clusters}$$

$$\frac{\text{Number of final clusters}}{\text{Total number of words}} \times 100 = \%\ \text{final clusters}$$

32	Does quality and quantity of speech reduce in unfamiliar contexts (situation, location, interlocutors, topic, etc)? or when a task is altered or when a new task is introduced (e.g., child seems to have mastered [s] sound but begins mispronouncing it when [ʃ] is introduced)?	
33	Does the child exhibit jargon speech ("speaking gibberish"; varied consonant and vowel patterns with appropriate intonation patterns, but no apparent meaning) in his / her speech?	
34	Does the child demonstrate difficulty with rate, rhythm, stress or intonation? or Is the child monotonous in his / her speech?	
35	Does the child show significantly higher receptive language skills than expressive language skills?	
36	Did the child show unusually slow progress in spite of intensive speech-language treatment in the past?	
37	Does the child show mildly low muscle tone? (Exclude extreme tone differences which are typical of CP)?	
38	Does the child exhibit limb apraxia: Fine and gross motor-planning difficulties, especially for action sequences (hands, whole body)?	
39	Does the child show mild to moderate sensory hypersensitivity, hyposensitivity, or both in different areas of the face and or body?	

Total score:

Clinical Impression:

Name & Signature of the Clinician:

APPENDIX II

ASSESSMENT TOOL FOR ORAL MOTOR, ORAL PRAXIS AND VERBAL PRAXIS SKILLS

Name:

Date:

Age/Gender:

Education:

School:

Other relevant information: