PROTOCOL FOR APPRAISAL OF VERBAL PRAXIS IN TYPICALLY DEVELOPING CHILDREN (4.0-6.0 YEARS)

Gaganashree R

Register No: 11SLP010

A Dissertation Submitted in Part Fulfillment for the Degree of

Master of Science (Speech - Language Pathology),

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI

MYSORE-570006

May, 2013

Certificate

This is to certify that this dissertation entitled "**Protocol for Appraisal of Verbal Praxis in Typically Developing Children (4.0-6.0 years)**" is a bonafide work in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No. 11SLP010). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

May, 2013

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing

Manasagangothri

Mysore -570006.

Certificate

This is to certify that this dissertation entitled "**Protocol for Appraisal of Verbal Praxis in Typically Developing Children (4.0-6.0 years)**" is a bonafide work in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No. 11SLP010). This has been carried out under my guidance and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

May, 2013

Prof. R. Manjula

Guide

Professor of Speech Pathology

Department of Speech-Language Pathology

All India Institute of Speech and Hearing

Manasagangothri,

Mysore-570006.

Declaration

This dissertation entitled "**Protocol for Appraisal of Verbal Praxis in Typically Developing Children (4.0-6.0 years)**" is the result of my own study under the guidance of Dr. R. Manjula, Professor of Speech Pathology, Department of Speech-Language Pathology All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

Mysore

May, 2013 Register No. 11SLP010

DEDICATED TO GOD, MY

LOVABLE FAMILY AND

FRIENDS

ACKNOWLEDGEMENTS

"Trust in the lord with all your heart, and lean not on your own understanding in all your ways acknowledge him, and he shall direct your path".....

I thank my **lord** for being with me always, supporting, providing strength and courage for whatever I do. Thank you god for being my strength and guiding me to a right path.....

I express my deepest gratitude and heartfelt thanks to my guide **Prof. R. Manjula**, professor of speech language pathology, Department of speech language pathology, All India Institute of Speech and Hearing, Mysore, for her excellent guidance, valuable suggestions, constant support, care and patience throughout this project. Thank you mam for bearing me and helping me throughout.....

I extend my sincere thanks to professor. **S.R. Savithri**, Director of All India Institute of Speech and Hearing, Mysore, for giving me an opportunity to undertake this project.

I also extend sincere thanks to **vasanthalakshmi mam** for her kindly help and support during this project. Thank you so much mam.I also thank **Santhosh sir** for his help and suggestions.

My beloved **Appaji** and **amma**.....'thanks' is a very small word... I'm very proud to have parents like you. A heartfelt thanks for both of you for your love, kind and care. I also thank for ur support, encouragement whenever I needed. You both became my strength and helped me reaching till here. Thank you so much for ur heartful prayers and blessings. Love you appaji and amma.....

Brother is just like a friend who supports, luv, care and help you in all your happiness and difficulties. I thank my sweet and lovely brother **Rahul** who is just lik a friend to me……

I extend my thanks to **Ajji, chikamma, Mallika mama, Rajesh mama, selva aunty and lovely sahana putti** for being with me as my backbone and helping me throughout my journey. I'm very lucky to have a family lik u…..A heartfelt thanks for all of u for ur luv, care and support. Luv u all…….

I also extend my sincere thanks to my lovely brothers **Madhu anna, Navi** for their great luv and care……

A **best friend** is someone who you can talk to, who won't judge u, luvs u for u, and most of all, makes u feel lik u r worth something. A special thanks to one such best friend **G.B (Munnu)** who is there with me in every event of my life helping, luving, caring, guiding and supporting me whenever I needed. U r one of my biggest strength…..I'll never miss u…luv u…

Real friends stick by you through the rough times as well as the good times. They will walk through all ur troubles to the other side with you holding ur hand. Very special and heartfelt thanks to one such true and great friend **Preethi** who is one of my biggest support. Very big thanks for ur great, luv, care, suggestions, support and sweet friendship. V'l b lik this forever…..luv u.

True friends believe in u, make u laugh, understand u, chill with u, comfort u, , trust u, help u, play with u, stick up for u. A heartfelt thanks for one such mad group **'GAMM model' - Amule, Puppy, Mahendra** who made my life more crazy and beautiful. Great thanks for all ur luv, care, valuable suggestions. U guys strengthened me by ur supporting and encouraging words. Hope this continues forever…….

I extend my greatful and special thanks to **Hellows, Zebu,Tanu, billu, Bhutha, Kapadpa** for their kindly support and encouraging words which helped me a lot throughout...thanku so much guys....

Friends are like beautiful flowers in the garden. Thanks for all such flowers who made my life more beautiful. A heartfelt thanks to **Suzi, shishira, Renju, Juttu, Nisha, sindhu** for ur kindly help, support, valuable suggestions, luv & care. We have a wonderful memories with us which are unforgettable (b'day parties, our PJ's, sleepless nights, movies, hostel fud, endless talks, marriage functions, small trips, shoppings, etc etc)....i will miss it.....

I'll not forget to thank my crazy and beloved classmates, the great '**Family Tree**' – specially **Mandira di & puja di** followed by **ceana, santhosh, edna, jyothsna chechi, nayana**.....I had a great fun with u guys..I'll never forget...thanks to all....

I extend my great thanks to all the **schools, students and staffs** of those schools who helped me a lot for my data collection.

I extend my heartfelt thanks to all my **seniors** and **juniors** who kindly helped me for my analysis. A special thanks to **Shailaja di** for ur kindly help, support and care.....

Lastly , I extend a big thanks to all the **staffs, seniors, juniors** and **friends** who made my graduation and post graduation life memorable and successful.....

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Speech is one of the most complex motor skills which involve various levels of organization and representative processes. Speech production involves skilled execution of the orofacial movements well coordinated in time with the laryngeal and respiratory activities controlled by fast and accurate motor control mechanism. These skilled behaviours are controlled by well tuned neuronal activities that regulate the muscles for speech production. At neuromotor level, different subsystems interact with each other to produce coordinated kinematic patterns within a complex and dynamic biochemical environment. At an acoustic level, complex aerodynamic manipulations of the vocal tract form different articulatory patterns. Speech is a result of complex movement patterns which require planning, programming and execution. Speech motor skills are acquired over a period of time and involves several developmental prerequisites such as neural, anatomical, physiological and musculoskeletal substrates. Infants have the innate capacity to learn verbal mode of communication earlier, but the pragmatic, linguistic, and perceptual- motor knowledge and skills which are required for the production and perception of speech are acquired later. Children learn speech motor control through imitation of acoustic patterns provided by "adult model" of language that represents the end point of the development continuum. Several studies support developmental changes of speech motor control as "speech motor age" (Miller, Rosin & Netsell, 1979). Various processes of articulation, voice, fluency and prosody achieve adult like precision in speech motor control starting by the age of six years and this is reflected as good speech motor control or "praxis". Studies have shown that speech motor control continues till the age of eight years and refinement period extends from eight to

twelve or fourteen years of age in typically developing children (Goffman & Smith, 1999; Green, Moore, Higashikawa & Steeve, 2000; Kent, 1976; Yan, 2007). Children tend to have slower speech rates and more variable amplitude, velocity, timing, and patterning of their articulatory movements (i.e., upper lip, lower lip, and jaw) compared to adults (Goffman & Smith, 1999; Green, Moore, Higashikawa & Steeve, 2000; Green, Moore & Reilly, 2002; Sharkey & Folkins, 1985; Smith & McLean-Muse, 1986; Smith & Goffman, 1998; Smith & Zelaznik, 2004; Walsh & Smith, 2002) Adult like performance is not reached until 14-16yrs of age and transition to more stable movement patterns and faster speech rate occurs very gradually with age (Smith & Zelaznik, 2004; Walsh & Smith, 2002).

"Praxis", a Greek word describes the process of action, performance and precision of motor skills. Praxis is very important for speech production in terms of articulatory movements and co-ordination between them. It involves different articulatory postures and seriated gestures. Verbal Praxis is affected in children with childhood apraxia of speech (CAS). CAS is considered as impairment of purposeful speech movements (Groenen, Massen, Crul & Thoonen, 1996; Hall, Jordan & Robin, 2007; Massen, Groenen & Crul, 2003). CAS is a controversial disorder with reference to its diagnosis and its representation as a motoric or linguistic-based impairment. Studies suggest that it is difficult to differentiate CAS from other speech disorders, especially in younger age groups is very difficult as they exhibit vague and inconsistent characteristics. There is no single diagnostic marker to differentiate CAS from other speech disorders (Stackhouse, 1992). A scale/test is required to overcome these difficulties in diagnosing and differential diagnoses of CAS from typical development. . Very few standard tests/scales are available for the assessment of

verbal praxis in CAS (Blakely, 1980; Hayden & Square, 1999; Kauffman 1995; Thoonen, Maassen, Witt, Gabreela & Shreuder 1996). These tests do not help in understanding the development of praxis in typically developing children. The existing scales which are developed to assess CAS are not sensitive enough to differentiate praxis deficits if any in typically developing children who are at risk for Apraxia of Speech, called as Suspected Apraxia of Speech (sAOS) and who are not at risk for Apraxia of Speech.

Radhika (2008) developed a modified protocol based on Rupela (2008) and Banumathy (2008), called "Assessment of oral motor, oral praxis and verbal praxis", to test typically developing children in the age range of 2 to 4 years for verbal praxis deficits. Radhika (2008) administered the protocol on verbal praxis development (which included 8 sections) on ninety typically developing children in three age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0. The performance of Typically developing children on some of the sections of the protocol showed developmental trend whereas others did not, suggesting that few of the tasks were sensitive in identifying features of sAOS in typically developing children aged 2 to 4 years. The protocol by Radhika (2008) provided norms for the age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0 years, that helps in early identification and intervention of children who are at risk for praxis breakdown.

Need for the study

There is a need to understand the normal praxis development of the children beyond 4 years of age in order to differentially diagnose children with CAS and sAOS. The criteria for diagnosing dyspraxia in children older than four years cannot

be applied to children lesser than four years of age (Thoonen, 1996, 1997, 1998). Radhika (2008) developed a standardized protocol to assess children with sAOS, especially for the verbal praxis breakdown by providing normative data for the Kannada speaking typically developing children in the age ranges 2.6 - 3.0, 3.0 – 3.6, 3.6 – 4.0 years. This study proposes to administer the protocol of Radhika (2008) to study the verbal praxis skills in children of older age groups (4 to 6 years). There is a need to study verbal praxis development in typically developing children of 4 to 6 years as verbal praxis skills are reported to continue to mature upto 8 years with a further refinement period extending to twelve or fourteen years in typically developing children (Goffman & Smith, 1999; Green, Moore, Higashikawa & Steeve, 2000; Green, Moore & Reilly, 2002; Sharkey & Folkins, 1985; Smith & Goffman, 1998; Smith & McLean-Muse, 1986; Smith & Zelaznik, 2004; Walsh & Smith, 2002). The study proposes to establish normative data for verbal praxis skills in typically developing children from 4 to 6 years which would further help to identify children with sAOS in this age range.

Aim of the study

1. To administer the protocol developed by Radhika (2008) for the assessment of verbal praxis in Kannada language on typically developing children aged 4.0 to 6.0 years.
2. To establish norms for the different tasks in the protocol based on the performance of children in four age groups (4.0-4.6, 4.6-5.0, 5.0-5.6, 5.6-6.0 years) of the study.

Method

A total of 120 Kannada speaking typically developing children were included in the study. The children were divided into four age groups (>4.0 - ≤ 4.6, >4.6 - ≤ 5.0, > 5.0 - ≤ 5.6, > 5.6- ≤ 6.0 years). Each group comprised of a total of 30 children including 15 girls and 15 boys. The children were selected from various schools in Mysore city. The children were screened for language function, oro-motor and oro-sensory skills.

The sections of the protocol includes:-

- Functional of oral mechanisms for speech
- Isolated of speech movements
- Sequential speech movements
- Word level praxis assessment- (i) Meaningful words, (ii) Non-Meaningful words
- Relational speech timing in word context
- Sentence level assessment
- Conversational assessment

The protocol was administered on the selected children in individual set up in a comfortable surrounding and without any distractions. The responses from the participants will be obtained through imitation of the words after hearing the verbal stimulus presented by the investigator. The children were given maximum of two trials and better of the two repetitions were considered for the analysis. The conversation sample was elicited by asking general questions about the child, his/her family, friends, school etc.

Analysis

Responses were recorded using video recorder. Reliability measures (intra and inter) was established for ten percent of the data. The recorded responses were transcribed and scored by the investigator for each task. A Speech Language Pathologist with post graduate degree served as judge for inter-rater reliability check of transcribed data & scoring for each section of the task after viewing the video recording of 10 percent of the data. The raw data was subjected to appropriate statistical measures. If 60 percent of the children in the given age group performed the task correctly, then the task was considered as having attained or developed by children of that age group.

Implications of the study

This scale will help in understanding the developmental trend if any in verbal praxis skills in typically developing children of 4 to 6 years & will aid in differential diagnosis of children with CAS & sAOS.

REVIEW OF LITERATURE

The Greek word 'Praxis', mainly describes the processing of action, performance and precise movement of motor skills. Praxis mainly involves planning, programming and execution of a motor act (Ayres, 1985). It plays a major role in the movement of articulators and coordination between them. 'Apraxia' is a disorder encompassed in controversy with respect to the definition, characteristics etc. Traditionally, 'Apraxia' is defined as a disorder where the individual is unable to produce any purposeful events without any paralysis, sensory impairments, intellectual disorders or problems in comprehension (Liepman, 1900).

Among all other speech disorders, Childhood Apraxia of Speech (CAS) is one of the speech disorders which is commonly seen in children and is often present since birth. It affects the child's ability of correct production of sounds, syllables and words. It is a disorder of controversy in the field of communication disorders. The confusion is mainly in terms of the label used to refer to children who show different and unusual speech patterns that are motoric in origin. Love (2000) described CAS as a disorder where in an individual is unable to program and execute voluntary motor gestures needed for the articulation of speech despite the absence of any muscular involvement. ASHA (2007) described CAS as 'speech sound disorder with neurological factors where the precision and consistency of movements of articulators are impaired without any neuromuscular deficits. CAS occurs in children due to neurological impairment, idiopathic or complex neurobehavioral disorders with known and/or unknown origin. The impairment is seen majorly in planning and/or programming of the tempero spatial parameters for a given sequence of movement

that result in speech sound production and prosody. The main controversy is whether CAS is an articulatory/phonological disorder, a language disorder, articulation with language disorder or language disorder which is secondary to speech deficits. The etiology and symptoms of the CAS are not clear and well established. Different investigators have different opinion in terms of the causes for CAS. Few believe that it is language disorder and few believe it as a neurological disorder. Studies on brain imaging and other related studies on children did not provide any evidence on the specific site of lesion or any differences in the brain structures. Few studies have shown evidence of children with CAS having family history of communication disorders or learning disabilities. Recent studies also suggested that genetic can be one of the factor that cause CAS in children.

The following are the common characteristics of children with CAS as given by different authors:

- Inconsistent production of vowels and consonants with repeated production of syllables or words (ASHA, 2007; Davis & Velleman, 2000; Rosenbeck & Wertz, 1972).
- Lengthened and disrupted coarticulatory transitions between sounds and syllables (Davis & Velleman, 2000).
- Inappropriate prosody, especially in the realization of lexical or phrasal stress (ASHA, 2007).

Additional characteristics of CAS reported include:

a. Speech characteristics
    - Inconsistency/ variability (ASHA, 2007)
        - Token-to-token variability

  - Phoneme error variability
  - Context variability
  - Positional variability
- Connected speech is more unintelligible than results on single word utterances (ASHA, 2007).
- Limited consonant and vowel repertoire (ASHA, 2007).
- Frequent vowel errors (Davis & Velleman ,2000).
- Predominant use of simple word shapes (ASHA, 2007)
- Frequent metathetic errors (Rosenbek & Wertz, 1972)
- Increased errors and inconsistency along with increased word shape complexity (Strand & McCauley, 2000).
- Limited vocalizations/ babbling during infancy (ASHA, 2007)
- Prominent phonemic errors: omissions (errors are more often omissions of syllables than substitution of sounds and syllables, substitutions, distortions, additions, repetitions, prolongations (Strand & McCauley, 2000).
- Repetition of sounds in isolation is often adequate; connected speech is more unintelligible than would be expected on the basis of single-word articulation test results (Rosenbek & Wertz, 1972).
- Differences in the performance of volitional versus automated speech (ASHA, 2007)
- Groping (Davis & Velleman, 2000)
- Persistent/ frequent regression (i.e loss of sounds or words) (ASHA, 2007)
- Poor Diadochokinesis (poor coordination and reduced stress) (ASHA, 2007)

- Predictable utterances produced more easily than novel utterances (Davis & Velleman, 2000).
- Slow progress in therapy and high resistance resistant to therapy used for other articulatory disorders (Aram & Glasson, 1979).
- Difficulty in achieving the initial articulatory configuration (Strand & McCauley, 2000)
- Speech development is delayed and deviant (Rosenbeck & Wertz, 1972)
- Frequent errors on the complex sounds like Fricatives (/s/, /z/, /ʃ/, etc), Affricates (/t ʃ/, /dz/), and consonant clusters (/st/, /sp/, /sl/, etc) (Strand & McCauley, 2000).

b. Nonspeech Motor characteristics (ASHA, 2007)

- Difficulty initiating and sequencing nonspeech oral movements.
- Possible drooling
- Feeding difficulty or history of feeding problems.
- Late attainment of motor milestones.
- Poor gross and fine motor coordination

Others (Aram & Glasson, 1979)

- Oral Apraxia may or may not exist (Strand & McCauley, 2000)
- Presence of some positive neurologic findings, including difficulties with fine and gross motor coordination, although neurologic findings are usually nonfocal.
- Failure to show a clear hand preference
- Poor gross and fine motor coordination.

c. Suprasegmental characteristics (ASHA, 2007)

- Prosodic disturbances (Davis & Velleman, 2000; Rosenbeck & Wertz, 1972).
- Prolonged pauses or breakdown between the phonemes, syllables, and words.
- Vocal pitch differences.
- Stereotyped or limited intonation patterns (Davis & Velleman, 2000).
- Rate differences (typically slow rate of speech).
- Lack of variation in vocal loudness.
- Resonance differences (hypernasality, hyponasality, or fluctuating resonance)

d. Linguistic characteristics

- Slow development of speech (Rosenbeck & Wertz, 1972) .
- Receptive language better than expressive language but sometimes receptive language also can be delayed (Aram & Glasson, 1979, Davis & Velleman, 2000, Rosenbeck & Wertz, 1972, Strand & McCauley, 2000).
- Morpho-syntactic difficulties (ASHA, 2007).
- There can be gaps and restrictions in the sound repertoire of the child (both consonant and vowel), including the possibility of the child acquiring the later developing sounds missing the earlier developing sounds (Davis & Velleman, 2000)
- Limited vocal output and regression in the vocabulary sometimes.

e. Educational characteristics

- Greater risk of reading, spelling and writing difficulties (Aram & Glasson, 1979; ASHA, 2007).

- Strong family history of speech, language and learning problems (Aram & Glasson, 1979).

Speech Language Pathologist should consider the features to diagnose children with CAS. The signs and symptoms can overlap with other speech and language disorders like Stuttering, Down's syndrome, Phonological disorder, Autism, Learning disability and others. The presence of apraxia can be expected in younger children who have limited verbal expression as a developmental feature. Such children are suggested as having suspected apraxia of speech and they are labeled as children with Suspected Childhood Apraxia of Speech (sCAS). Studies have suggested that 'errors in the production of stress', is a major diagnostic marker for children with sCAS (Shriberg, Kwiatkowski, & Rasumen, 1990). Comparison of children with sCAS, functional articulation disorders and PD revealed that children with sCAS exhibit following characteristics:

- Slow diadochokinetic rates (Yoss & Darley, 1974)
- Difficulty sequencing auditorily presented stimuli (Aram & Horowitz, 1983)
- Limited phonological systems (Thoonen, Maasen, Gabreels, & Schreuder, 1994);
- Difficulty with auditory discrimination and rhyming tasks (Marion, Sussman, & Marquardt, 1993; Yoss & Darley, 1974);
- Decreased strength and endurance of the oral articulators (Murdoch, Attard, Ozanne, & Stokes, 1995; Robin, Somodi, & Luschei, 1991).

The core diagnostic features exhibited by children with sCAS as cited by various authors are as follows:

- Differences in the errors of children with the developmental speech delay (Shriberg ,1997)
- Errors resemble that of the adults with acquired apraxia of speech (Shriberg, 1997)
- Variability in errors (David, Jakielski, & Marquardt, 1998)
- Vowel errors (David, Jakielski, & Marquardt, 1998)
- Prosodic abnormalities (David, Jakielski, & Marquardt, 1998)
- Poor perception and/or representation of syllable structure (Marquardt, Sussman, Snow, & Jacks, 2002)
- Linguistic stress (Munson et.al, 2003).
- Longer vowel duration (Peter & Gammon, 2005).

It is difficult to distinguish CAS from other speech and language disorders as the characteristics overlap between them (Guyette & Diedrich, 1981). Stackhouse (1992) cites three major factors that leads to difficulty in differential diagnosis of CAS from other speech disorders include:

- Lack of detailed description of the speech sound errors that are found in children with CAS.
- Problems in methodology in terms of subject selection criteria
- Lack of developmental perspective.

Studies that have attempted to differentially diagnose CAS have listed some characteristics that are yet to serve as appropriate diagnostic markers to differentiate

CAS from other speech sound disorders. There is lack of knowledge regarding the development of praxis and its influence on developing linguistic system in children. A list of speech characteristics has been proposed by several authors in children with CAS which may not be seen in children of all age groups. The characteristics of the disorder should consider the developmental level of the child as the condition changes according to the demands during the development of the child. Stackhouse (1992) concluded that there is no single diagnostic marker for CAS. Shriberg and Campbell (2003) supported and suggested that the symptoms in children with CAS changes over time.

There is no single diagnostic marker that is universally accepted in diagnosing children with CAS, suggesting that there is lack of appropriate diagnostic procedures and guidelines for the diagnosis of children with CAS. Inconsistency and variability of speech sounds is considered as the major diagnostic marker in diagnosing children with CAS according to few authors and the controversy still exists regarding the diagnosis of this disorder. Therefore the major solution is to develop appropriate scales/tests for the assessment of verbal praxis in children. Few studies have focused on the development of oral praxis in young toddlers and children. Kools and Tweedie (1975), assessed the performances of 87 normal male children between the age range of one to six years on four measures of praxis: oral praxis command, oral praxis demonstration, limb praxis command and limb praxis demonstration. The results revealed that all the measures of praxis control were developed by one year of age and reach near normal performance by six years of age. The oral praxis demonstration emerged earlier than the limb praxis demonstration. The developmental changes of speech motor control are supported by several studies which have addressed the

concept of “speech motor age” (Miller, Rosin, & Netsell, 1979). Studies have shown that speech motor control continues till the age of eight years and refinement period extends from eight to twelve or fourteen years of age in typically developing children (Kent, 1976; Yan, 2007; Green, Moore, Higashikawa, & Steeve, 2000; Goffman & Smith, 1999). Children tend to have slower speech rates and more variable amplitude, velocity, timing, and patterning of their articulatory movements (i.e., upper lip, lower lip, and jaw) compared to adults (Goffman & Smith, 1999; Green, Moore, Higashikawa, & Steeve, 2000; Green, Moore & Reilly, 2002; Sharkey & Folkins, 1985; Smith & Goffman, 1998; Smith & McLean-Muse, 1986; Smith & Zelaznik, 2004; Walsh & Smith, 2002). A transition to more stable movement patterns and faster speech rate occurs very gradually with age, and adult performance is not reached until fourteen to sixteen years of age (Smith & Zelaznik, 2004; Walsh & Smith, 2002).

Few standard tests have been proposed by different authors for the assessment of verbal praxis in children with DAS. There are very limited tests for the toddlers and young children. Blakely (1980) developed a test called ‘Screening Test for Developmental Apraxia of Speech’ (STDAS), for the differential diagnosis of developmental apraxia of speech. It consists of eight subtests which include:

- Discrepancy between the expressive and receptive language ability.
- Vowel and diphthongs
- Oral-motor movement
- Verbal sequencing
- Articulation
- Motorically complex words

- Transpositions
- Prosody

Meline and Howard (1981) reviewed STDAS and noted the absence of external criteria, such as expert opinion, neurologic evaluation, or related test results to indicate the validity of the STDAS. Guyette and Diedrich (1983) criticized STDAS by concluding that there is no sufficient agreement in clinical findings or in experimental studies that support the conclusion that characteristic symptoms of the CAS have been adequately identified.

Hayden and Square (1999), proposed a scale called the "Verbal Motor Assessment for Children (VMPAC)" for children in the age range of three to twelve years. This test assesses the neuromotor integration of motor speech system in children who have speech production disorders within the given age range. It mainly assesses the global motor control, speech and non-speech oral motor control, sequential control of speech and non speech movement sequences, precision and control of the articulators during connected speech. It describes the overall speech characteristics (resonance, vocal quality, prosody etc) and helps in the diagnosis of the developmental apraxia of speech.

Nancy Kaufmann (1995) also developed a test called "The Kaufman Speech Praxis Test (KSPT)" for the age range of 2-6 years to identify the level of breakdown in a child's speech. The test helps in diagnosis and treatment of developmental apraxia of speech. The test items include meaningful words that are arranged from simple to complex motor speech movements. It helps in the assessment of imitation of

oral movements, simple and complex phoneme production, simple to increasingly complex word shapes, and overall speech intelligibility. It also provides analysis and descriptive elements of other behaviors that are observed during speech production of the child (groping, inconsistency, vowel distortions, atypical phonological patterns etc). It provides normative and standardized items that give a raw score, a standard score and a percentile ranking for each section of the test. This helps in describing severity levels on a continuum and also normative information related to the normal speaking children compared to the disordered population. The results obtained from KSPT are useful beyond establishing an initial diagnosis of the child and its individual section can be used to establish the treatment goals.

Thoonen, Massen, Wit, Gabreels, & Schreuder, (1996) developed a protocol to assess the maximum performance abilities of the children. The measures such as Maximum Phonation Duration (MPD), Maximum Fricative Duration (MFD), Maximun Repetition Rate for single syllables (MRR mono), Maximum Repetition Rate for tri-syllables (MRR tri) were included as diagnostic measures to assist in the differential diagnosis of pediatric client with Dyspraxia and Dysarthria. The prolongation tasks such a prolongation of /a/ and the word /mama/ yielded Maximum Phonation Duration (MPD), prolongation of /f/, /s/ & /z/ yielded maximum fricative duration (MFD) and repetitions of /pa/, /ta/, /ka/, /pataka/ did not help as the potential indicators of Dysarthria or Dyspraxia in the given age group. Repetition rates were stable both within and across children but the prolongation tasks were highly variable in both the conditions. Thus they concluded that MRR mono can be an effective measure for children in the age range of 4-6 years but MPD measure could lead to misdiagnosis.

Blackley (2001) developed another screening test for children with DAS in the age range of 4.0- 12.11 years. Before administering the test, a pre screening task need to be carried out (comparison of receptive and expressive language abilities). If the client passes in this task, three subtests are administered which includes: verbal sequencing, articulation and prosody. This was administered on children with DAS and children with normal speech development and standardized. This screening instrument indicates the need of additional and more specific speech and neurological evaluation.

The scales mentioned above are developed mainly to assess childhood apraxia of speech. These scales usually contain only those features as test items which are sensitive enough to diagnose the disordered population. These scales/tests are not based on the praxis development in typically developing children. Thoonen, Massen & Gabreels (1997) attempted to propose a standardized procedure to differentially diagnose CAS from other disorders. It includes three components:

- Firstly, Elicitation and analysis of true word and nonsense word imitation was used as a standardized assessment procedure and also validated as an adequate procedure to measure relevant speech symptoms of CAS.
- Secondly, the scores of three parameters: error counts of substitution, omissions and cluster reductions were combined which turned out to be an adequate measure of severity of CAS.
- Thirdly, comparison between the error rates in true words and nonsense words which is an important speech characteristic of CAS, which could contribute for the differential diagnosis.

The results of the study indicated the importance and need for a standardized procedure and also the need to analyze a comprehensive set of speech characteristics that allows for the assessment of a speech profile in children with CAS. These studies suggest that a validated test/scale is required for a definite diagnosis of CAS and differentially diagnose from other speech and language disorders. The test/ scale should assess the verbal praxis in typically developing children and allow the clinician to know the patterns of speech praxis control during the course of development of the child. Such scale must help to differentiate typically developing children from children at risk for verbal praxis breakdown as in sCAS.

Radhika (2008) developed a modified protocol based on Rupela (2008) and Banumathy (2008) to test typically developing children in the age range of 2 to 4 years for verbal praxis deficits. This protocol was meant to test verbal praxis development in typically developing children. Radhika (2008) included an additional task of "Test of relational speech timing in words" along with the other tasks of verbal praxis section of Rupela (2008) and Banumathy (2008) as it reflects on the timing inaccuracies and inconsistencies in the speech of individuals with apraxia of speech. The protocol on verbal praxis development (which included 8 section) was administered on ninety typically developing children in three age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0. The performance of Typically developing children on some of the sections of the protocol showed developmental trend whereas others did not, suggesting that few of the tasks were sensitive in identifying features of sAOS in typically developing children aged 2 to 4 years. The protocol by Radhika (2008) provided norms for the age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0 years, that helps in early identification and intervention of children who are at risk for praxis breakdown.

There are no standardized tests/scales that assess the normal praxis development of the children beyond 4 years of age as the praxis development continues till eight years of age and refines till 12-14years of age (Goffman & Smith, 1999; Green, Moore, Higashikawa & Steeve, 2000; Green, Moore & Reilly, 2002; Sharkey & Folkins, 1985; Smith & Goffman, 1998; Smith & McLean-Muse, 1986; Smith & Zelaznik, 2004; Walsh & Smith, 2002).The criteria for diagnosing dyspraxia in children older than four years of age cannot be applied to children lesser than four years of age (Thoonen, 1996, 1997, 1998). Thus the present study proposes to establish normative data for verbal praxis skills in typically developing children from 4 to 6 years which would further help to identify children with sAOS in this age range.

METHOD

Aim of the study

3. To administer and adopt the assessment protocol developed by Radhika (2008) for the assessment of oral and verbal praxis in typically developing Kannada speaking children aged 2.6 to 4 years (in 6 months age interval) for the typically developing Kannada speaking children aged 4.0 to 6.0 years.
4. To establish norms for the different tasks in the protocol based on the performance of children in four age groups (> 4.0 - ≤ 4.6; > 4.6- ≤ 5.0; > 5.0- ≤5.6; > 5.6- ≤ 6.0 years) selected for the study.

Participants

A total of 120 Kannada speaking typically developing children were included in the study. The children were categorized into four groups based on the age (> 4.0 - ≤ 4.6; > 4.6- ≤ 5.0; > 5.0- ≤5.6; > 5.6- ≤ 6.0 years) Each group comprised of a total of 30 children including 15 girls and 15 boys. The children were selected from various schools in Mysore city.

Selection criteria for the participants

- The first language was Kannada and second language was English.
- They had normal language functions (screened using the "Development of an intervention module for preschool children with communication disorders" by Swapna, Jayaram Prema and Geetha, 2010); oro-motor and oro-sensory skills (screened using the "oro-motor section" of the Screening Test for Developmental Apraxia of Speech, by Blackley, 1980); and oral structural abnormalities (based on oral mechanism examination by the investigator).

- Children with history of any neurological and medical conditions were excluded.

The Test Protocol: Content and Scoring pattern.

There were no Standard test/ scales available in Kannada that assess verbal praxis in typically developing children. Radhika (2008) proposed a protocol which is based on a tool called "Assessment of oral motor, oral praxis and verbal skills" developed by Rupela (2008) and Banumathy (2008) to test typically developing children in the age range of 2 to 4 years for verbal praxis deficits. Radhika (2008) included an additional task of "Test of relational speech timing in words" along with the other tasks of verbal praxis section of Rupela (2008) and Banumathy (2008) as it reflects on the timing inaccuracies and inconsistencies in the speech of individuals with apraxia of speech. This protocol was administered on typically developing Kannada speaking children in the age range of 2 to 4 years in order to assess for the developmental pattern if any in praxis development. . Radhika (2008) provided norms for the age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0 years, that helps in early identification and intervention of children who are at risk for praxis breakdown. The purpose of the study is to administer the protocol developed by Radhika (2008) for the assessment of verbal praxis in Kannada language on typically developing children aged 4.0 to 6.0 years and also establish norms for the different tasks in the protocol based on the performance of children in four age groups ($> 4.0 - \leq 4.6$; $> 4.6- \leq 5.0$; $> 5.0- \leq 5.6$; $> 5.6- \leq 6.0$ years) of the study. The details of the sections of the protocol are summarized in Table 1.

Table 1

Sections of the protocol developed by Radhika (2008)

Section No.	Sections
I	Function of oral mechanisms for speech
II. A	Isolated speech movements
II. B	Sequential speech movements
II. C	Word level praxis assessment in a) Meaningful words b) Nonmeaningful words
II. D	Relational word timing in word Context- monosyllables & bisyllables
II. E	Diadokinetic assessment
II. F	Verbal praxis in sentences
II. G	Verbal praxis in conversation

The protocol is presented in Appendix A. The details of the sections included in the protocol are as follows:

Test 1: Function of the oral mechanism of speech

This section was included majorly to assess adequacy of oral mechanism as required for verbal praxis behaviors, especially for oral-nasal distinction, air pressure build up for the sops, fricatives, and range of movement of articulators. This section includes 6 tasks. The participants are instructed to imitate the investigator for the activities. Scores of 0 – 1 is given for inadequate and adequate performance respectively.

Test II.A. Isolated speech movements

The stimulus includes 24 items including vowels, continuant consonants and CV syllables with consonants that occur in initial position in Kannada and those which predominantly use jaw, lip and tongue structures for the utterance. The participants are asked to imitate the sounds after the investigator and a repetition of two is provided if the child fails to utter once or is unable to do it or perform the task

inappropriately. The performance of the participants is assessed using a 4-point rating scale. The rate of the movement of the articulators during the production is not considered. Each item in the task is scored based on the accuracy of the movement and whether repetitions are required, and if so, based on number of repetitions to perform the task, score is assigned. Score of 0-3 is given as follows: 3 – Movement / action is accurate; 2 – Movement / action with one repetition; 1 – Movement/ action is inappropriate with more than one repetition; 0 – Child is unable to perform even with repetitions.

Test II.B: Sequential speech movements:

This section is considered to increase the level of complexity of the task for the assessment of verbal praxis deficits. It is taken from the 'Multiple oromotor-phoneme (speech) movements' section of VMPAC (Hayden & Square, 1999). The stimulus under this section gives scope to two to three sequential speech movements. This section incorporates utterance of vowels and continuant /m/. The participants are instructed to imitate the speech movements as produced by the investigator. Initially the sound is produced once by the investigator and if the child fails to imitate, it is repeated three times in a sequence and the child is asked to imitate the sequence. The ability of the child to produce the sequence is analyzed and scored.

Two types of scoring is done; 'Motor control score' and 'Sequential motor score' in order to calculate the appropriateness of movements and maintenance of sequence respectively. Scoring is done as follows based on the responses given by the participants:

Motor Control Score (MCS):

‘2’ – All movements are precise in every parameter

‘1’ – one or all movements are partially imprecise in one of more parameters

‘0’ – one or all movements are severely imprecise in one or more parameters or child substitute’s one phoneme for another or child does not say all phonemes.

Sequence Maintenance Score (SMS):

‘2’ – Repeats all phonemes in the sequence correctly.

‘1’ – Repeats 2 out of 3 sequences correctly or repeats the phonemes 5 0r 6 times

‘0’ – Repeats one out of 3 sequences correctly or repeats the phoneme sequence more than 6 times.

If the child does not respond to the task due to inability to do so and not due to the noncompliance or inattentiveness, then the particular item is marked as NR (No Response) and a score of ‘0’ is given.

Test II. C: Word level praxis assessment

Two types of stimuli were incorporated in this section: (i) Meaningful words & (ii) Non-meaningful words.

(i)Meaningful words:

180 commonly occurring Kannada words that differ in syllable length and presence of clusters are compiled from a pictorial glossary of Kannada (Kumari & Mallikarjun, 1985) by Rupela (2008) & Banumathy (2008). Forty most familiar words: five words each from disyllabic, tri-syllabic and multisyllabic structure with and without clusters is included. Words included are arranged in a hierarchy of increasing length, complexity and presence of clusters as follows: Disyllabic words without clusters; Disyllabic words with clusters; Tri-syllabic words without clusters;

Tri-syllabic 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; Tri-syllabic words with two clusters-one in the initial and one in the medial position. The participants are asked to imitate the words uttered by the investigator. The responses of the participants are analyzed in two ways.

(a) Number of words correct: All words were transcribed using the Broad transcription of International Phonetic Alphabet (IPA) and total numbers of words produced correctly are tabulated.

(b) Syllable sequence score: This is calculated to assess the sequence of syllables maintained within the word. The number of syllables that are misplaced or exchanged in terms of sequence is noted. A score of '0' to '2' are given as follows:

Sequence maintenance score-disyllabic words:

2 - Repeats both syllable in the correct order

1 - Repeats both syllable in reverse order or adds an extra syllable or repeats a syllable, consonant cluster reduction / deletion, consonant harmony, vowel harmony.

0 - Repeats only syllable or does not repeat any syllable in the correct order.

If the child does not respond, it is scored as 'no response (NR)' with score 0.

Sequence maintenance score – tri-syllabic and multisyllabic words:

2 - Repeats all syllables in the correct sequence

1 - Repeats all syllable except one in the correct sequence or any one syllable in reverse order or addition of a syllable, consonant cluster reduction / deletion, consonant harmony, vowel harmony.

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

If the child does not respond, it is scored as 'no response (NR)' with score 0. The scores were not reduced for consonant / vowel substitution unless where consonant / vowel harmony occurred as repetition of syllables and deletion or reduction of syllables occurred as a result of consonant cluster reduction or deletion.

(ii) Non-meaningful words: Totally 4 sets of words are included with each set consisting of 5 words and thus totaling 20 words. The responses of the subjects on imitating the investigator are recorded and transcribed using broad transcription of International Phonetic Alphabet (IPA). The responses are scored as follows:

(a) Number of words correct: The total numbers of words produced correctly.

(b) Syllable sequence score: This is calculated to analyze whether the sequence of syllable is maintained. The number of syllables that are misplaced or exchanged in sequence within each word is analyzed.

Test II. D: Relational speech timing in word context:

A list of meaningful words (4 monosyllables & 4 bi-syllables) is included. This task consists of 8 base words with three levels of increasing utterance lengths due to suffixes added to the base word. Totally 24 stimuli items are present. In each set of words, the first stimuli (RST-I) is the Base Word (BW) condition. The second set of stimuli (RST-II) is the Base Word + Suffix I (BW+SI) condition, and the third stimuli (RST-III) is the Base Word + Suffix II (BW+SII) condition. All of the base words and their suffix conditions are meaningful words. The target words are uttered by the investigator and they are imitated by the participants. The responses of the

participants are transcribed using broad transcription method of International Phonetic Alphabet (IPA). The responses are scored as follows:

(a) Number of words correct: Number of words correct for each set.

(b) Syllable sequence score: analyzed for the ability to maintain syllable sequence by the participants. The number of syllable that are substituted or exchanged in terms of sequence is noted per utterance.

In all the three subsections in word level praxis assessment (meaningful words, non-meaningful words and, relational speech timing task), phonological processes are analyzed and they are categorized as space errors, timing errors, whole word errors and others.

Task II. E: Diadochokinetic Assessment

The participants are instructed to repeat the syllables /pa/, /ta/, /ka/, (SMR-Sequential Motion Rates) and /pa/, /ta/, /ka/, independently (Alternative Motion Rates-AMR) as fast as they can. If the child fails to follow instructions, they are given clues by tapping a finger for every syllable and progressively moving it upwards. The analysis of the responses of the participants is made in terms of rate, accuracy and consistency of the production. A maximum of two attempts are given to produce a minimum of ten iterations per trial to each child. The scoring / analysis are carried out in the following ways:

a. Attempts: A maximum of two attempts are given to each child, and the best attempt with at least ten iterations is considered for calculations of DDK rate.
b. Scoring for Accuracy: Responses of all the subjects are rated for accuracy with respect to articulation. If the first four repetitions are accurately produced, a score of 1 is given and 0 if the repetitions are inaccurate.

c. Scoring for consistency: In order to evaluate consistency of productions in the DDK tasks, the following scoring procedure is used: '3'- Consistent repetitions; no change from one repetition to the next; '2'- three of the four repetitions are consistently repeated; '1'- Two of the four repetitions are consistently repeated; '0'- all repetitions are different from one another.

d. DDK rate: DDK rate is calculated using the following formula.

$$\text{DDK rate} = \frac{\text{Total number of iterations}}{\text{Duration of trial}} \text{ (Iterations/second or it/sec)}$$

Task II. F: Sentence Level Praxis Assessment

Ten sentences arranged hierarchically based on the syllable length is included. The shortest sentence has the syllable length of three syllables and the longest sentence has twelve syllables. The shortest sentence has the word length of two words and the longest sentence has six words. The subjects are instructed to repeat each sentence after the investigator and each response is transcribed using the broad IPA system of transcription. The analysis is carried out in two ways:

(a) Number of sentences correct: The total number of sentences produced correctly.

(b) Sequence maintenance scores for sentences: The responses of the participants are scored on the basis of number of words in the sentences, i.e. sentences are considered as belonging to two groups, (i) lesser than three words & (ii) greater than three words. A three point rating scale is used for scoring the responses in lesser and greater than 3 words as follows: 2- All the words are in the exact order or position / child uses a consistent phoneme substitution; 1- Sentences with $\leq$ 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 $\leq$ 3 words – 0 words in order; Sentences with > 3 words – 2, 1 or no key words are in order. If the child does not respond due to inability to do

so and due to noncompliance or inattentiveness, then the item is marked as NR (no response) and score of '0' was given.

Task II. G: Conversational analysis / analysis of spontaneous speech:

A spontaneous speech sample of at least a hundred utterances is collected from each child by eliciting general conversation about home, routine, and school. The recorded sample of at least a hundred utterances of each child is transcribed using the broad system of IPA transcription. The child is engaged in conversation for approximately three minutes. A conversation sample of one minute of each child is considered and approximately 15-20 words appearing in the middle of the sample is taken for analysis. The conversation sample is analyzed using Percentage Consonant Correct (PCC) and Percentage Vowel Correct (PVC) measures. Before the analysis of PCC, the following data are excluded from the sample: Unintelligible and partially intelligible utterances; Vowels; Consonants which are repeated for the third time or more on repetition of the same word, if the pronunciation did not change. But if the pronunciation changes, all the consonants are included for scoring. The following are considered when the sample is analyzed for consonant errors: Dialectal changes, casual speech pronunciation and allophonic variations are not scored as incorrect; Consonant deletions are scored as incorrect; Consonant substitutions are scored as incorrect; Partial voicing are scored as incorrect; Distortions are scored as incorrect; Additions of consonants are scored as incorrect.

Before the analysis of PVC, the following data are excluded from the sample: Unintelligible and partially intelligible utterances; Consonants; Vowels which are repeated for the third time or more on the same word, if the pronunciation did not change, but if pronunciation changed, all the vowels are included for scoring.

The errors in the remaining data were identified using the following criteria: Dialectal changes, casual speech pronunciation and allophonic variations are not scored as incorrect; Vowel deletions are scored as incorrect; Vowel substitutions are scored as incorrect; Distortions are scored as incorrect; Additions of vowels are scored as incorrect.

PCC scoring: The total number of consonant errors is tallied from the transcribed samples and the Percentage of Consonants Correct (PCC) are calculated using the formula as follows:

$$PCC = \frac{\text{Total number of correct consonants}}{\text{Total number of consonants attempted}} \times 100$$

PVC scoring: The total number of vowel errors was tallied from the transcribed samples and the percentage of vowels correct (PVC) are calculated using the formula as follows:

$$PVC = \frac{\text{Total number of correct vowels}}{\text{Total number of vowels attempted}} \times 100$$

Administration of the Protocol:

The demographic information of each child such as name, age with date of birth, education and school, was obtained and the tasks in the protocol were administered to each child in comfortable, non distractible surroundings. All children were tested individually in relatively quiet and familiar surroundings. The investigator uttered the stimuli with correct articulation and with correct rate, giving adequate time for the child to respond. The responses were elicited by asking the child to imitate the words after hearing them. A minimum of two repetitions were given for each

stimulus. The better of two repetitions was considered for analysis. The conversation sample was elicited by asking general questions about the child's name, friends, family, house, school etc. Reinforcements were given whenever required. The child's responses were recorded online using Canon ZR 90 Digital video camcorder and were converted into DVDS for permanent storage with microphone kept approximately 10 cm from the child's mouth. Each participant was also provided with intermittent breaks whenever required based on the temperament of the child. Total recording time ranged from 20 minutes to 30 minutes per child depending on the co-operation of the child.

Reliability:

Reliability was checked for the test protocol and the rating scores. Since, the protocol involved the use of different rating scales for each task, the scoring system was subjected to variability. Two types of reliability measures (inter-judge & intra-judge reliability) were carried out.

Inter-judge reliability: A judge matched in gender, education, and work experience with the investigator was identified for the task. The judge was explained about the scoring pattern of the various tasks. Video recordings of the testing by the investigator were done on ten percent of the data (i.e. nine children), for reliability measures. Video recording were done using Canon ZR 90 Digital video camcorder and were converted into DVDS for permanent storage. The video camera was placed on a table in front of the child and investigator and the child were seated side by side. Video recording was started along with the administration of the test battery where positive feedback and appropriate cues were given in order to elicit the appropriate response from the child. These recorded videos were viewed by the judge on a 20

inches wide computer monitor. The responses of twelve children randomly selected from different age groups and across sex were analyzed by the judge based on the video samples. The scores of these subjects scored by the judge and the investigator was compared and the reliability co-efficient alpha was calculated.

Intra-judge reliability: Ten percent of the participants (i.e. twelve children), were administered the test protocol for the second time by the investigator after a gap of six weeks. The scores obtained by the participants during the first and the second analysis were compared and the reliability co-efficient alpha was calculated for the same.

The results are tabulated and discussed in the next chapter.

RESULTS AND DISCUSSION

Aim of the study

1. To administer the protocol developed by Radhika (2008) for the assessment of verbal praxis in Kannada language on typically developing children aged 4.0 to 6.0 years.
2. To establish norms for the different tasks in the protocol based on the performance of children in four age groups (> 4.0 - ≤ 4.6; > 4.6 - ≤ 5.0; > 5.0 - ≤ 5.6; > 5.6 - ≤ 6.0 years) of the study.

The protocol was administered on 120 typically Kannada speaking children in the age range of 4 to 6 years, subdivided into four age groups with thirty children in each age group (equal male and female ratio). The protocol was administered on the children individually by the investigator and in most of the tests and subtests, imitated responses of the children after the investigator was observed. The responses of the children were recorded using a Canon ZR 90 Digital video camcorder. Correct performance by 60 % of children in the subgroup on the task/s of a particular test/subtest was considered as the criteria to indicate development of skill tapped in that test/subtest. The raw scores on the various sections of the protocol were tabulated for each child and later for the group. Descriptive analysis was carried out to calculate Mean, Median and Standard Deviation. Percentage scores were calculated to verify the 60% criteria. 2-way MANOVA was carried out to compare across age and gender, and Duncan's test (parametric test) was carried out to compare across the parameters.

The results are presented under the following headings:

A. Function of oral mechanism for speech
B. Isolated speech movements
C. Sequential speech movements
D. Word level praxis assessment - (i) Meaningful words, (ii) Non-Meaningful words
E. Relational speech timing in word context
F. Sentence level assessment
G. Conversational assessment

I. Function of the oral mechanism for speech

In this section, the six tasks assessed the adequacy/inadequacy of function of the oral mechanism required for speech in terms of intra-oral air build-up for stops and fricatives, oral-nasal distinction, range of movement of different articulators such as lip, jaw and tongue. Table 2 illustrates the mean score and standard deviation of children across all the four age groups.

Table 2

Mean and SD for performance in function of the oral mechanism of speech in children across all the four age groups

Age	Maximum score	Mean	SD
> 4.0 - ≤ 4.6	6	6.00	0.00
> 4.6 - ≤ 5.0	6	6.00	0.00
> 5.0 - ≤ 5.6	6	6.00	0.00
> 5.6- ≤ 6.0	6	6.00	0.00

Note. SD=Standard deviation

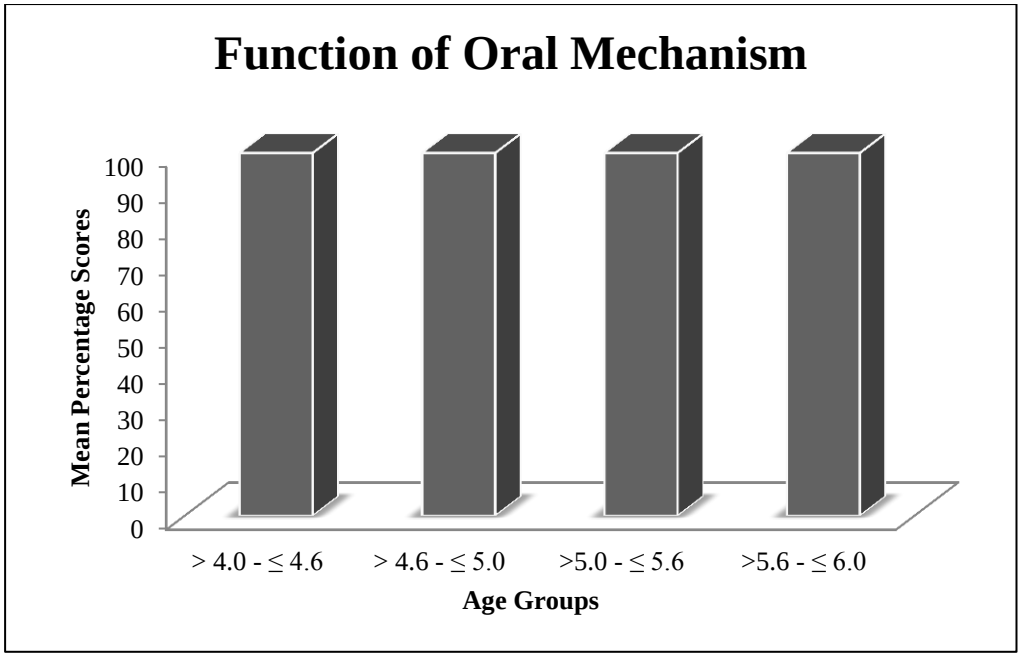


Figure 1. Mean percentage scores of four age groups on function of the oral mechanism for speech

Figure 1 illustrates the performance of children across the four age groups based on the percentage calculated on function of the oral mechanism for speech. Descriptive statistics was carried out and mean and standard deviation was calculated. Two – way MANOVA was carried out to see the difference across age and gender and there was no significant difference across age and gender. The maximum scores were attained by all the subgroups starting from the youngest group studied suggesting that the skills assessed to test the function of the oral mechanism for speech has attained complete maturation by 4 years. Similar study by Robbins and Klee (1987) on children aged 2.6 to 6.11years to assess the structure, function, rate, and durational measures reported no significant difference in the structure but differences were found in the functioning especially in the age range of 2.0 to 3.11years which was attributed to developmental motor processes responsible for oropharyngeal skills including the motor system organization that produces relatively

consistent opening movement durations, open posture durations, and inter-articulatory timing of lip and jaw movements (Sharkey & Folkins, 1985). The plateau reached in this function by 4 years of age also suggests “fine tuning" of motor system by this period meaning that this test is not applicable to children above 4 years as the skill has achieved maturity before 4 years of age. The same protocol administered on Kannada speaking children aged 2.6 to 4.0 years by Radhika (2008) revealed that most of the children were able to perform accurately and reached maximum scores suggesting maturity by 3.6 to 4.0 years of age. The result of this study further confirms the observation made by Radhika (2008).

II. Verbal Praxis Assessment

a. Isolated Speech Movement

This section included a total of twenty-four tasks, and these tasks aimed to assess the movements of jaw, lip and tongue. The jaw and lip movements were assessed using five tasks each and tongue movement were assessed using fourteen tasks. Table 3, illustrates the mean and standard deviation of the isolated speech movements of jaw, lip and tongue across the four different age groups studied. Figure 2 shows the mean percentage scores for these movements across the four age groups.

Two-way MANOVA was carried out to compare across the age and gender across the four age groups. It was found that there was no significant difference across gender for jaw [$F(1,112) = 2.00$, $p > 0.05$], lip [$F(1,112) = 2.57$, $p > 0.05$] and tongue movements [$F(1,112) = 0.028$, $p > 0.05$]. There was no significant difference across age for jaw [$F(3,112) = 0.66$, $p > 0.05$], lip [$F(3,112) = 0.19$, $p > 0.05$] but there was significant difference across tongue movements [$F(3,112) = 5.96$, $p < 0.05$].

Table 3

Mean and Standard deviation of the Isolated Speech Movement – Jaw, Lips and Tongue movements

Age group (In years)	Jaw movement		Lip movement		Tongue movement	
	Max score	Mean (SD)	Max score	Mean (SD)	Max score	Mean (SD)
> 4.0 - ≤ 4.6	15	14.96 (0.18)	15	14.93 (0.36)	42	38.46 (3.52)
> 4.6- ≤ 5.0	15	14.96 (0.18)	15	14.90 (0.40)	42	38.76 (2.56)
> 5.0- ≤ 5.6	15	15.00 (0.00)	15	14.96 (0.18)	42	40.46 (1.97)
> 5.6- ≤ 6.0	15	15.00 (0.00)	15	14.93 (0.36)	42	40.93 (2.62)

Note. SD=Standard deviation

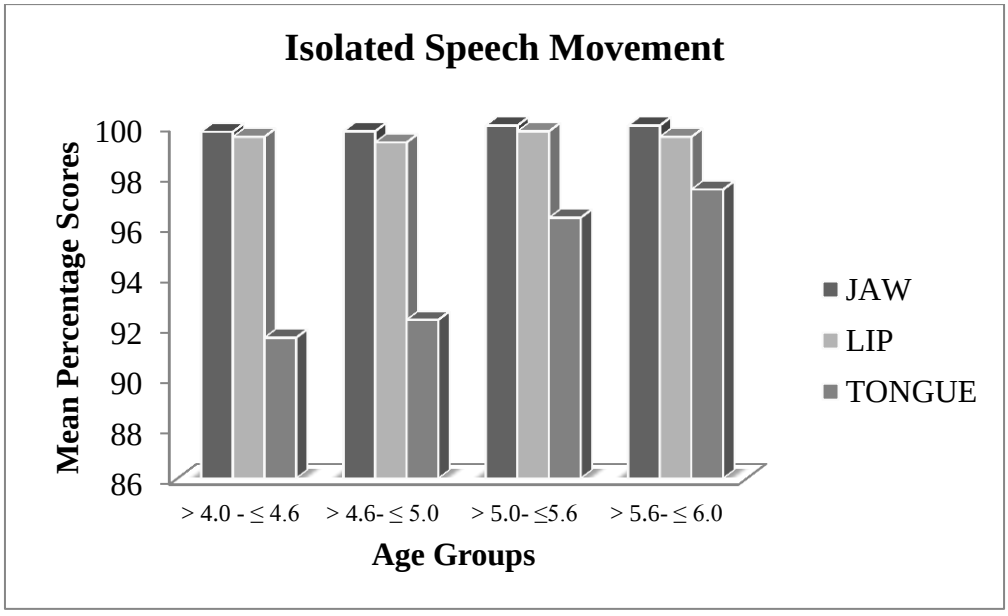


Figure 2. Mean percentage scores of four age groups on isolated speech movements of Jaw, Lip and Tongue

As there was difference found across age groups, Duncan's Post Hoc test was carried out to compare the parameters across age groups and the results showed that there was significant difference for tongue movements while there was no significant difference for jaw and lip movements.

It may be seen from Table 3 that the maximum possible scores were the same across all the age groups suggesting that twenty-four tasks were equally well performed by the children above four years. There was no developmental trend evident for jaw and lip movements as the scores were the same across the four age groups, but tongue movements showed some developmental trend. The SD for tongue movements in general was high suggesting immature control of praxis in the tongue compared to the lips and jaw.

Although 60% of the children in the subgroups were able to perform all the twenty-four tasks, it was found that few children across the four age groups exhibited errors in the production of sounds such as /t/, /d/, /t̪/, /d̪/, /r/, /ʃ/, /s/, /ɭ/, /l/, /n/. The study by Radhika (2008) revealed reduced mature performance in children of older age group (3.6 – 4.0 years) than the younger age group. Radhika (2008) observed that 60% of the children in the age group 2.6 – 3.0 years were not able to produce the sound /ʃ/. In this study, children across all the age groups were able to perform all the twenty four tasks but few children showed persistent errors in the production of /t/, /d/, /t̪/, /d̪/, /r/, /ʃ/, /s/, /ɭ/, /l/, /n/ sounds. There could be two reasons (i) immaturity in speech sound acquisition (ii) it is known that production of s/ʃ varies among Kannada speakers of rural and urban spoken languages.

II. B. Sequential Speech Movements:

This section included a total of seven tasks. In this section the responses were scored in two ways:

1. Motor Control Score (MCS)
2. Sequence Maintenance Score (SMS)

Table 4 illustrates the Mean and Standard Deviation for the sequential speech movements across the four age groups. Figure 3 shows the Mean percentage scores for sequential movements across the four age groups.

Table 4

Mean and Standard deviation for Sequential speech movements across the four age groups

Age groups (In years)	MCS			SMS		
	Maximum Scores	Mean	SD	Maximum Scores	Mean	SD
> 4.0 - ≤ 4.6	14	12.30	1.14	14	12.36	1.09
> 4.6 - ≤ 5.0	14	12.56	1.33	14	12.63	1.35
> 5.0 - ≤5.6	14	13.06	1.08	14	13.06	1.08
> 5.6 - ≤ 6.0	14	12.83	1.23	14	12.83	1.23

Note. SD=Standard deviation

(a) Motor control score (SSM - MCS):

This parameter was based on the judgment and rating for appropriateness of the movements executed. The children were instructed to imitate the sequence of vowels and consonants produced by the investigator. In the statistics, Two-way MANOVA was carried out to compare the performance across age and gender. There was no significant difference across gender [$F(1,112) = 2.12$, $p > 0.05$] and between age groups [$F(3,112) = 2.32$, $p > 0.05$].

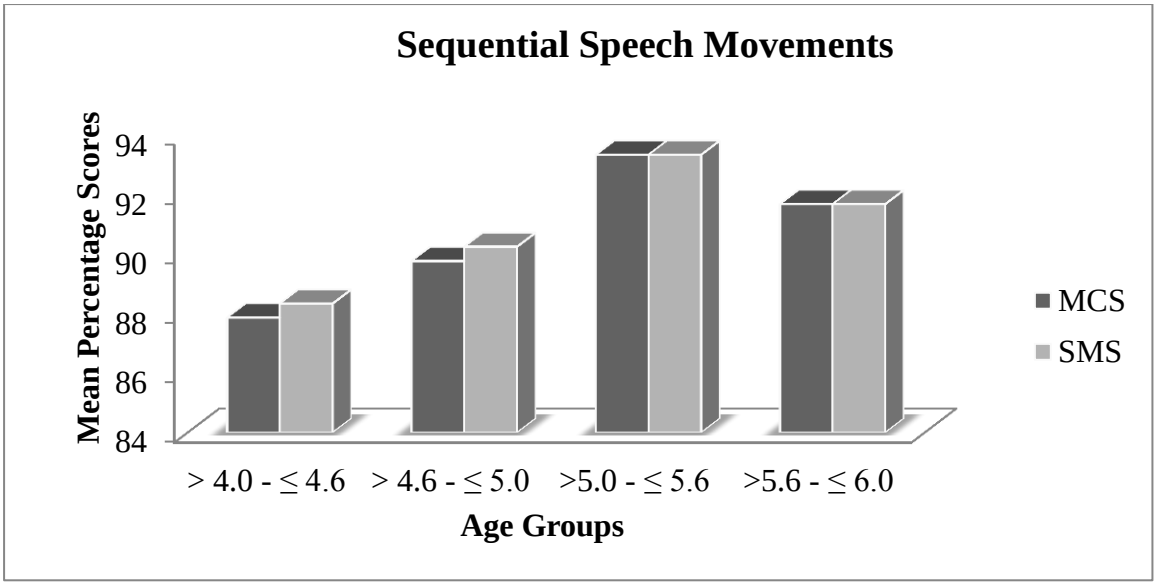


Figure 3. Mean percentage scores of four age groups on Sequential Speech Movement tasks

Duncan's post hoc test was carried out to compare the parameters across age groups and the results showed that there was no significant difference across age groups.

Children of all the four age groups attained 60% criteria in all the seven tasks. But it was also found that, most of the children above four years had difficulty in task 5 (repetition of speech sound sequence, o-m-i), task 6 (repetition of speech sound sequence, a-m-u) even though they passed the criteria of 60%. When a bilabial nasal sound /m/ is placed between two vowels, it requires co-ordination between the oral and the nasal port associated with alternative opening and closing of lips. Most of the children produced errors wherein the nasal sound /m/ was preceded by a vowel sound (a- am- u, a- am- u, o – am- i, o – am – i). The vowels substituted were often /a/ or /u/. This could be explained as due to the complexity of the task and the difficulty in co-articulation of the voicing feature. This also suggests that, Task 5 & 6, which included

imitation of the VCV chain of /o-m-i/ and /a-m-u/ could be considered as sensitive measures in the assessment of errors in praxis control. That is, group of children with sAOS may be predicted to show more difficulty in this combination of VCV.

From Table 4, it is observed that the maximum score is the same across the four age groups, suggesting that children above four years were able to perform optimally for all the seven tasks. The Mean and Standard deviation was highly variable across the four age groups suggesting the possibility of lack of developmental trend in this age group or maturity in these task performances. It was also found that, even though 60% of the children were able to perform most of the tasks in this section, the performance of few children was not always accurate, across all four age groups, suggesting that the process of maturation of speech motor control is probably incomplete. From figure 3, it is observed that the performance of children in the younger age group was better than the older group in few instances. Example, child in age group > 5.0 - ≤ 5.6 performed better than the age group > 5.6 - ≤6.0 years and this can be attributed to subject variability in the groups.

Study by Radhika (2008) revealed that the children in the age group 2.6 to 3.0 years did not meet the criteria in three tasks; task 3 (m-u), task 5 (o-m-i) and task 6 (a-m-u). Also, children in the age group 3.0 to 3.6 years could not attain criteria 60% in two tasks; task 5 (o-m-i) and task 6 (a-m-u). This was attributed by Radhika (2008) as due to the complexity of task involved in producing them even with two to three repetitions. In this study, children across four age groups were able to perform all the seven tasks, except a few who exhibited difficulty in the production of task 5 (o-m-i)

and task 6 (a-m-u). This suggests that all the seven tasks are valid for the assessment of praxis while task 5 and 6 could be more sensitive in assessing praxis failures.

(b) Sequence Maintenance Score

The sequence maintenance score was based on the ability of the children in repeating the sequence of appropriate vowels and consonants in the given stimulus. This section includes seven tasks. Two-way MANOVA was carried out to compare across age and gender. There was no significant difference across gender [$F(1,112) = 1.69$, $p > 0.05$] and age [$F(3,112) = 1.86$, $p > 0.05$]. Duncan's Post Hoc Test was carried out to compare the parameters across the age groups and the results showed that there was no significant difference across the age groups.

The children above four years were able to perform all the seven tasks in the section. But children across the four age groups showed the same pattern of difficulty in the tasks as found in MCS task. That is, on task 5 and task 6 (o-m-i) and (a-m-u) respectively. Children showed more errors, probably suggesting the higher potential of these two tasks in tapping the risk for praxis failure.

From Table 4, it is observed that the maximum score was the same across the four age groups suggesting that children above four years were able to perform all the seven tasks although they were arranged in a hierarchy of complexity from simple to complex. The mean and standard deviation was highly variable across the four age groups suggesting lack of developmental trend.

Figure 3 shows the percentage scores derived from the mean raw scores for both MCS and SMS across four age groups. There was no developmental trend seen across the four age groups. The performance of children was the same in both motor control and sequence maintenance.

Radhika (2008) in her study revealed that, out of seven tasks, the children in the age group 2.6 to 3.6 years were able to perform only one task (a-u). The children in the age group 3.0 – 3.6 years were able to perform four out of seven tasks and failed to perform the sequential tasks /o-m-I/, /a-m-u/ and /u-i-a/, the children in the age group 3.6 to 4.0 years failed to perform the task 5 (o-m-i). In the present study, children in the four age groups were able to perform all the seven tasks, where some children exhibited difficulty in performing the sequential tasks for /a-m-u/ and /o-m-i/.

I. C. Word Level Praxis

It included two sub sections: Meaningful Words and Non-Meaningful Words.

i. Meaningful Words:

Meaningful Words were divided into 8 subgroups as follows:

- DNC - Disyllable No cluster (without cluster)
- DWC - Disyllabic with cluster
- TNC - Trisyllabic No Cluster
- TWC - Trisyllabic with cluster
- MNC - Multisyllabic No Cluster
- MWC - Multisyllabic With Cluster
- D2C - Disyllabic with two clusters
- T2C - Trisyllabic with two clusters

The target words varied in complexity of their production across these subgroups. The responses of children was scored in two ways: (a) Number of Words Correct (NWC) (b) Syllable Maintenance Score (SMS)

Table 5

Mean and Standard deviation for word level praxis –Meaningful words across the four age groups

Age groups (In years)	NWC			SMS		
	Maximum scores	Mean	SD	Maximum scores	Mean	SD
> 4.0 - ≤ 4.6	38	30.20	4.17	78	69.86	4.74
> 4.6 - ≤ 5.0	38	29.10	5.55	78	69.13	5.57
> 5.0 - ≤ 5.6	40	34.53	3.30	80	74.50	3.28
> 5.6 - ≤ 6.0	40	34.63	3.71	80	74.56	3.94

Note. SD=Standard deviation

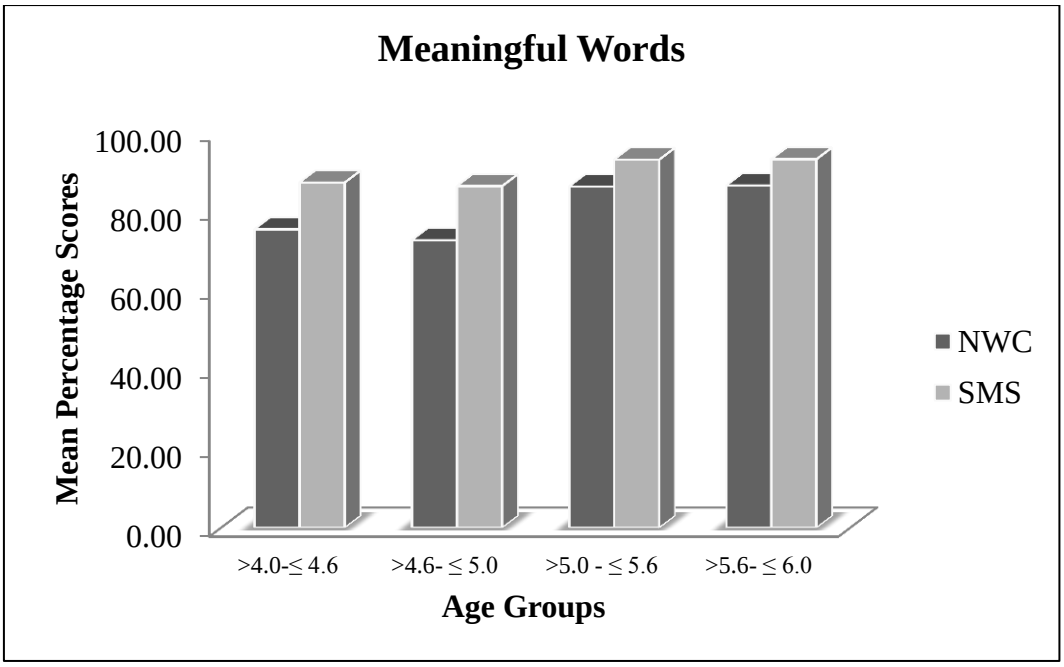


Figure 4. Mean percentage scores across four age groups on word level praxis assessment- Meaningful words (MW)

(a) Number of Words Correct (MW-NWC) :

This section includes a total of forty tasks, with five target words in each subgroup. Two-way MANOVA revealed no significant difference across gender [F (1,112) = 0.219, $p > 0.05$]; no age difference for the subsection TNC [F (3,112) = 1.52, $p > 0.05$] but there was significant difference for the other subsections: DNC [F (3,112) = 8.24, $p < 0.05$], TWC [F (3,112) = 4.70, $p < 0.05$], MNC [F (3,112) = 2.94, $p < 0.05$], MWC [F (3,112) = 6.05, $p < 0.05$], D2C [F (3,112) = 10.76, $p < 0.05$] and T2C [F (3,112) = 3.74, $p < 0.05$]. Duncan's Post Hoc Test was carried out for all the parameters except TNC. The results showed that there was significant difference across age groups.

Out of forty tasks, children in the age group > 4.0 - ≤ 4.6 years were able to perform 30 tasks, children in the age group > 4.6 - ≤ 5.0 years were able to perform 29 tasks; the children in the age group > 5.0- ≤5.6 years were able to perform 35 tasks; and the children in the age group > 5.6 - ≤ 6.0 were able to perform 35 tasks out of forty tasks. The children were not able to perform most of the tasks listed below:

- DWC - Disyllabic with cluster
- TWC - Trisyllabic with cluster
- MWC - Multisyllabic With Cluster
- D2C - Disyllabic with two clusters
- T2C - Trisyllabic with two clusters

In other words, children could not reach 60% criteria for the words with clusters. The younger age groups > 4.0 - ≤ 4.6 years and > 4.6 - ≤ 5.0 years failed to reach 60% in the subsections of DWC, TWC, MWC, D2C and T2C whereas the older

age groups > 5.0 - ≤ 5.6 years and > 5.6 - ≤ 6.0 years failed to reach 60% in the subsection T2C.

The errors were more in clusters due to the complexity involved in producing clusters. Various studies have suggested that the errors increase as the complexity and length of the utterance increases, and this is considered one of the diagnostic markers in assessing praxis failure in children with CAS (Forrest, 2003; Strand & McCauley, 2000).

Overall, a clear developmental trend with the increase in age was evident in this task. The SD also decreased as age increased, suggesting reduced variability indicative of maturation in children in older age groups (> 5.6 - ≤ 6.0 years). Figure 4, shows the mean percentage scores for the number of words produced correctly by the children across all the age groups on meaningful words.

Generally, children in all the four age groups showed difficulty in producing clusters. This is similar to the observation made by Banu (1977) in a study on articulatory development in Kannada speaking children wherein the blends and clusters were found to be acquired completely by 6 years of age. Prathima (2009) in her study on Kannada speaking children revealed that most of the clusters are acquired with 90% accuracy by 3-3.6 years of age and few clusters are acquired with 75% accuracy by 4 years of age. But the age for complete acquisition of all the clusters was not mentioned in the study. In the present study, most of the children had difficulty in producing target words with clusters, thus refuting the observation of Prathima (2009) and supportive of the findings reported by Banu (1977).

Radhika (2008) in her study revealed that out of forty tasks, children attained 60% criteria as follows: 2.6-3.0 years - twenty-one tasks, 3.0-3.6 years - twenty-seven tasks and 3.6 to 4.0 years - 33 tasks. Children failed to reach 60% criteria for the subsections DWC, TSC, MWC, D2C, and T2C and continued to present difficulty in producing the target words in the section MNC due to the complexity of the words. In the present study, children could not reach 60% for the sections which consisted of target words with clusters.

(b) Syllable Maintenance Score (MW – SMS):

This section is based on the ability of the children in sequencing the syllables in a given target word. It includes forty tasks. Two-way MANOVA was carried out and there was no significant difference across gender [$F(1,112) = 0.041$, $p > 0.05$], but there was significant difference across the four age groups [$F(3,112) = 12.71$, $p < 0.05$]. Duncan's Post Hoc Test was carried out to compare across the parameters and there was significant difference across age groups.

Children across the four age groups failed to reach 60% in the subsection T2C (Trisyllabic with two clusters). Out of forty tasks, the children of different age groups performed as follows: $> 4.0 - \leq 4.6$ years - thirty seven tasks; $> 4.6 - \leq 5.0$ years - thirty eight tasks; $> 5.0 - \leq 5.6$ years - thirty eight tasks and $> 5.0 - \leq 5.6$ - thirty nine tasks. Errors in the clusters can be supported by the findings of the previous study by Banu (1977) and Prathima (2009). Prathima (2009) in her study on Kannada speaking children revealed that most of the clusters are acquired with 90% accuracy by 3-3.6 years of age and few clusters are acquired with 75% accuracy by 4 years of age. But the age for complete acquisition of all the clusters was not mentioned in the study by

Prathima (2009). Banu (1977) studied the articulatory development in Kannada speaking children and suggested blends and clusters are acquired completely by 6 years of age. In the present study most of the children had difficulty in producing target words with clusters, thus refuting the observation of Prathima (2009) and supportive of findings reported by Banu (1977).

Radhika (2008) in her study revealed that out of forty tasks, children in different age groups attained 60% criteria as follows: 2.6-3.0 years - thirty tasks; 3.0-3.6 years - thirty-one tasks; and 3.6 to 4.0 years - thirty-seven tasks. Children failed to reach 60% for the subsections D2C, T2C due to difficulty involved in the sequencing of clusters. In the present study, the children could not reach 60% criteria for the section T2C that consisted target words with two clusters.

From Table 5, it is found that the maximum scores increased with age, which suggested that a number of tasks were more easily produced by the older age group than the younger age group. The mean scores also increased for the older age group suggesting a clear developmental trend. The Standard Deviation scores are variable, higher for the younger age groups and lower for the older age groups; suggesting improved performance and maturation of praxis control in the older age group. Figure 4 shows the mean percentage scores of the four age groups on syllable maintenance score. The findings suggest that the performance of children is better for the syllable sequencing than the word production. This is, children were able to maintain the sequence of the syllables though they did not produce correctly.

(ii) Non-meaningful words (NMW):

This section included a total of twenty non-meaningful words divided into four sets: (a) Set A (I), (b) Set A (II), (c) Set B (I) and (d) Set B (II). Each set consisted of 5 non-meaningful words. The scoring was carried out in two ways:

(a) Number of words correct (NWC)

(b) Syllable maintenance score (SMS)

Table 6 represents the Mean and Standard Deviation for the performance of the children across the four age groups. Figure 5 shows the mean percentage scores on the performance of children on non-meaningful words across the four age groups.

Table 6

Mean and Standard deviation for Word Level Praxis –Non-Meaningful words across the four age groups.

Age groups (In years)	NWC			SMS		
	Maximum Scores	Mean	SD	Maximum Scores	Mean	SD
> 4.0 - ≤ 4.6	19	15.83	2.13	37	35.76	2.19
> 4.6 - ≤ 5.0	20	15.30	3.94	39	35.30	3.94
> 5.0 - ≤ 5.6	20	18.13	1.38	40	38.13	1.38
> 5.6 - ≤ 6.0	20	17.66	1.80	40	37.66	1.80

Note. SD=Standard deviation

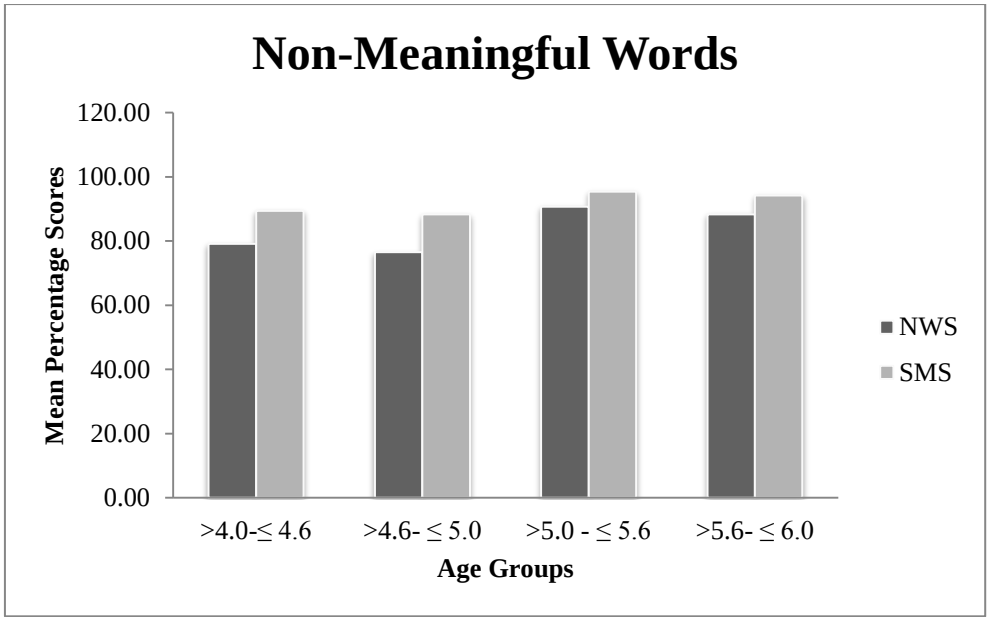


Figure 5. Mean percentage scores across four age groups on word level praxis assessment- Non-Meaningful words (MW)

Duncan's Post Hoc Test was carried out to compare the parameters across the age groups and the results showed there was significant difference across the age groups. Out of twenty tasks, children attained 60% criteria as follows: > 4.0 - ≤ 4.6 years - fifteen tasks; > 4.6 - ≤ 5.0 years - fifteen tasks; > 5.0 - ≤ 5.6 years - nineteen tasks; and > 5.6-≤ 6.0 years - eighteen out of twenty tasks. The children could not reach 60% in the subsets; set A (II), set B (I), set B (II).

Out of twenty tasks, children across different age groups failed to attain 60% criteria as follows: > 4.0-≤ 4.6 years - one word from set A (II), two words from set B (I) and two words from set B (II); > 4.6-≤ 5.0 years - two words from set B (I) and three words from set B (II); > 5.0-≤5.6 years - one word from set B (I); and > 5.6-≤ 6.0 years - one word from set B (I) and one word from set B (II). This is due to increased complexity of the target word which could be considered as sensitive measures in the assessment of errors in praxis control.

From Table 6, it is found that the maximum scores increased along with age, which suggested that a number of tasks were more easily produced by the older age group than the younger age group. The mean scores increased along with the age, which depicts the developmental trend, but a clear developmental trend is not seen. It was observed that the performance of the children in the younger age groups > 4.0 - ≤ 4.6 years and > 5.0 - ≤ 5.6 years were better than the older age groups > 4.6- ≤ 5.0 years and > 5.6 - ≤ 6.0 years respectively. The Standard Deviation are higher for the younger age groups and lower for the older age groups suggesting improved performance and maturation of praxis control in the older age group. Figure 5 shows the mean percentage scores with respect to the non-meaningful words that were correct, across all the four age groups.

Radhika (2008) in her study found that out of twenty tasks, children attained 60% criteria as follows: 2.6- 3.0 years - thirteen tasks; 3.0-3.6 years - fourteen tasks; and 3.6 - 4.0 years - seventeen tasks. The children failed to reach 60% for the set B (I) and set (II). In the present study, children could not reach 60% in the subsets; set A (II), set B (I), set B (II). This suggested that performance decreased as the complexity of production increased further suggesting that they are sensitive enough in assessing praxis deficits.

(b) Syllable Maintenance Score (NMW – SMS):

This parameter is based on the ability of the children in maintaining appropriate sequence of the syllables. Two-way MANOVA was carried out and there was no significant difference across gender [F (1,112) = 1.367 p > 0.05], but there

was significant difference across the four age groups for the subsections: Set A(I) [F (3,112) = 1.253, $p < 0.05$]; Set A(II) [F (3,112) = 4.708, $p < 0.05$]; Set B(I) [F (3,112) = 7.987, $p < 0.05$]; Set B(II) [F (3,112) = 7.131, $p < 0.05$]. Duncan's Post Hoc Test was carried out to compare the parameters across the age groups and the results revealed that there was significant difference across the age groups. This section included a total of twenty tasks. Out of twenty tasks, children of different age groups performed as follows: > 4.0-≤ 4.6 years and > 4.6-≤ 5.0 years - one task in set B (II); > 5.0-≤5.6 years and > 5.6-≤ 6.0 years - all twenty tasks.

From Table 6, it is seen that maximum and mean scores increased with age, suggesting that the number of applicable to the older age group was more. The Standard Deviation scores are variable and higher for the younger age groups and lower for the older age groups suggesting improved performance and maturation of praxis control in the older age group. Figure 5 shows the mean percentage scores of the four age groups in terms for syllable sequence maintenance. The findings suggest that the performance of children for syllable maintenance is better than the correct production of words. That is, children were able to maintain the sequence of the syllables easily than producing correctly.

Radhika (2008), in her study found that the children in the age group 2.6 to 3.0, 3.0 – 3.6 and 3.6 to 4.0 years attained 60% criteria for fifteen words and eighteen out of twenty words respectively; suggesting that the performance of children decreased as the complexity of the words increased. Radhika (2008) further suggested that increasing complexity of words could be a sensitive measure in assessing children

who are at risk for suspected apraxia of speech. The present study supports the findings of Radhika (2008).

II. D. Relational Speech Timing Tasks:

It was an additional task added to the protocol by Radhika (2008) along with the other tasks of verbal praxis section of Rupela (2008) and Banumathy (2008). This task reflects on the timing inaccuracies and inconsistencies seen in the speech of individuals with apraxia of speech (Forest, 2003; Roggers, 1997; Strand & McNeil, 1996). This section includes a total of twenty-four meaningful words/tasks. The words were divided into eight sets with three words in each (stimuli 1, stimuli 2, and stimuli 3) which increased in its length progressively from stimuli 1 to stimuli 3. The first stimulus was considered as the base/root word followed by addition of one suffix to the base word in stimuli 2. Similarly, the third stimuli consisted of two suffixes in order to increase the length of the word. The scoring of the responses of children was done in two ways:

(a) Number of words corrects (NWC)

(b) Syllable maintenance score (SMS)

Table 7 (a) and figure 6 (a), 8 (b) and figure 6 (b) illustrates the mean and SD for the number of words correct scores and sequence maintenance scores respectively of children across the four age groups on relational speech timing in word context.

Table 7 (a)

Mean and Standard Deviation of the number of words correct scores obtained in relational speech timing tasks across the four age groups

Age groups (In years)	NWC-RST I			NWC-RST II			NWC-RST III		
	Max Score	Mean	SD	Max Score	Mean	SD	Max Score	Mean	SD
> 4.0-≤ 4.6	8	7.53	0.68	8	6.93	0.69	8	6.70	0.74
> 4.6-≤ 5.0	8	7.80	0.55	8	7.20	0.71	8	6.80	1.06
> 5.0-≤5.6	8	7.96	0.18	8	7.70	0.46	8	7.46	0.73
> 5.6-≤ 6.0	8	8.00	0.00	8	7.63	0.49	8	7.46	0.50

Note. SD=Standard deviation, NWC-RST I= Number of Words Correct-Relational Speech Timing I, NWC-RST II= Number of Words Correct-Relational Speech Timing II, NWC-RST III= Number of Words Correct-Relational Speech Timing III.

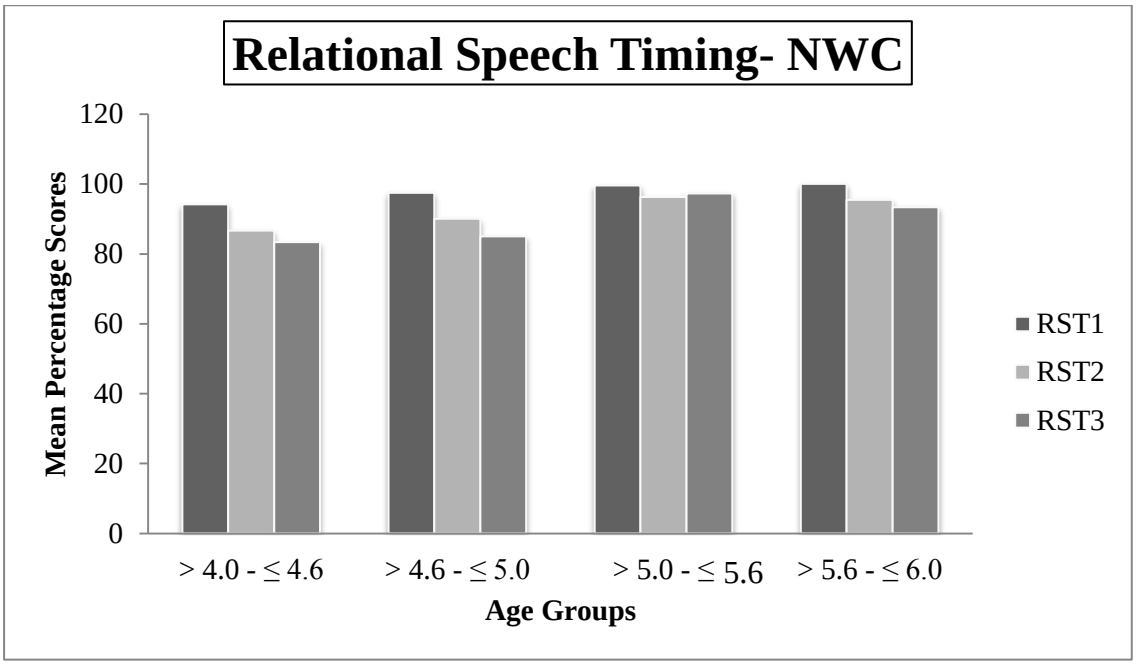


Figure 6 (a). Mean percentage scores of four age groups on relational speech timing tasks on number of word correct

Table 7 (b)

Mean and SD of the sequential maintenance scores obtained in relational speech timing tasks across the four age groups

Age groups (In years)	SMS-RST I			SMS-RST II			SMS-RST III		
	Max Score	Mean	SD	Max Score	Mean	SD	Max Score	Mean	SD
> 4.0-≤ 4.6	16	15.53	0.68	16	14.93	0.69	16	14.70	0.74
> 4.6-≤ 5.0	16	15.80	0.55	16	15.20	0.71	16	14.76	1.19
> 5.0-≤5.6	16	15.96	0.18	16	15.70	0.46	16	15.46	0.73
> 5.6-≤ 6.0	16	16.00	0.00	16	15.63	0.49	16	15.46	0.50

Note. SD=Standard deviation, SMS-RST I= Sequential Maintenance Score-Relational Speech Timing I, SMS-RST II= Sequential Maintenance Score-Relational Speech Timing II, SMS-RST III= Sequential Maintenance Score-Relational Speech Timing III

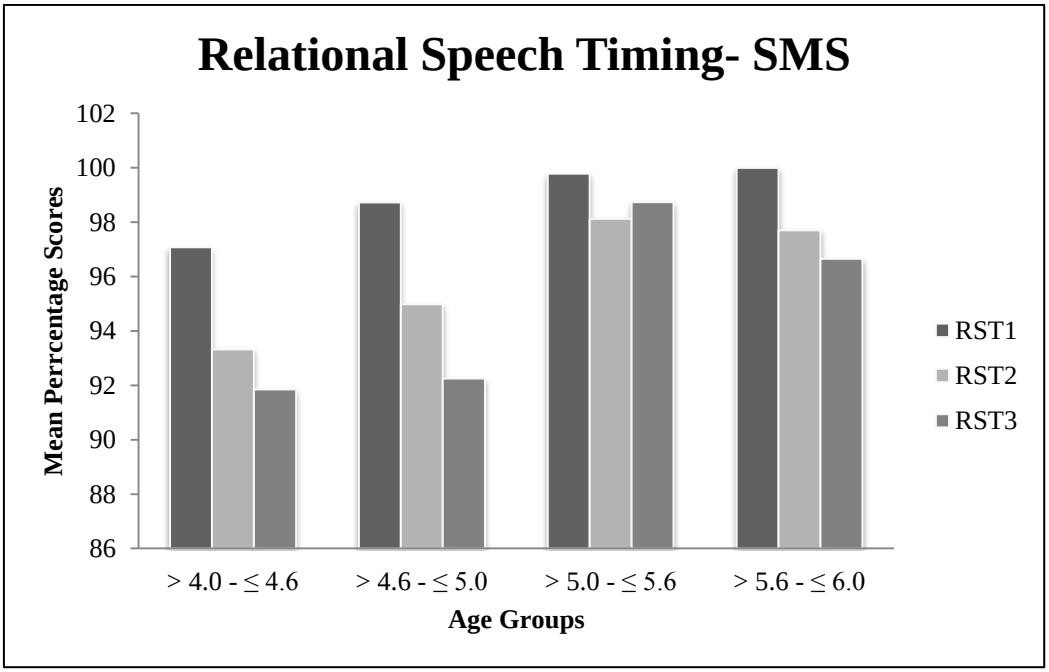


Figure 6 (b). Mean percentage scores of four age groups on relational speech timing tasks of sequence maintenance score

(a) Number of Words Correct (NWC)

This section included a total of twenty-four words. Two-way MANOVA was carried out and there was no significant difference found across gender [F (1,112) = 1.256 p > 0.05] but there was significant difference across the four age groups for the subsections: RST-I [F (3,112) = 6.622, p < 0.05]; RST-II [F (3,112) = 11.064, p < 0.05]; RST-III [F (3,112) = 8.508, p < 0.05]. Duncan's Post Hoc Test was carried out to compare the scores across the age groups and the results showed there was significant difference across the age groups. Out of twenty-four tasks, children of different age groups performed as follows: > 4.0 - ≤ 4.6 years and > 4.6 - ≤ 5.0 years - twenty-three tasks; > 5.0- ≤ 5.6 years - twenty-four tasks; and > 5.6 - ≤ 6.0 years - twenty-three tasks out of twenty-four tasks. The children did not attain 60% criteria for the eighth set of words under stimuli 2 and 3. This can be attributed to fact that these stimuli consisted of syllables, which were not produced accurately by children. Along with this, the length of the utterance also increased and hence children could have found it difficult to produce the words correctly.

Table 7(a), shows that the maximum score was same across all the age groups suggesting that all the tasks were equally well performed by children above four years. The mean scores increased gradually along with increase in age, suggesting that a developmental trend across the four age groups. But the developmental trend was not clear, since, it was observed that performance of the children in the younger age group > 5.0-≤5.6 years was better than the older age group > 5.6-≤ 6.0 years. The Standard Deviation scores were higher for the younger age group and lower for the older age group, suggesting improved performance and maturation of praxis control in the older age group.

Radhika (2008), in her study revealed that out of twenty-four tasks, children attained 60% criteria as follows: 2.6 - 3.0 years and 3.0 - 3.6 years - twenty tasks, 3.6 - 4.0 years - twenty-three tasks. Children failed to reach 60% criteria in the stimuli 3 condition (RST-III). This was probably because of the increased difficulty in articulating multisyllabic words due to increased length of utterance. In the present study, children could not reach 60% criteria for stimuli 2 and 3 within the eighth set of words.

(b) Syllable Maintenance Score (SMS):

This section included a total of twenty-four words. Two-way MANOVA was carried out and there was no significant difference across gender [$F(1,112) = 1.314$ $p > 0.05$] and there was significant difference across the four age groups for the subsections: RST-I [$F(3,112) = 6.622$, $p < 0.05$]; RST-II [$F(3,112) = 11.064$, $p < 0.05$]; RST-III [$F(3,112) = 7.875$, $p < 0.05$]. Duncan's Post Hoc test was carried out to compare the parameters across the age groups and the results showed that there was significant difference across the age groups. Out of twenty-four tasks, children of different age groups attained 60% criteria as follows: > 4.0-≤ 4.6 years and > 4.6-≤ 5.0 years - twenty-three tasks; > 5.0-≤5.6 years and > 5.6-≤ 6.0 years - all twenty-four tasks. The children in the age groups > 4.0-≤ 4.6 years and > 4.6-≤ 5.0 years could not reach 60% criteria for the eighth set of words in RST-II and RST-III. This was due to the inappropriate production of words and difficulty in producing the word due to its increased length of utterance.

From, Table 7 (b) it is evident that the maximum score is the same across all the age groups suggesting that children above four years were able to perform optimally for all the tasks. The mean scores were higher for the older age group suggesting a developmental trend across the four age groups. . The Standard Deviation scores are variable and higher for the younger age groups and lower for the older age groups suggesting improved performance and maturation of praxis control in the older age group Figure 6 (b) shows the mean percentage scores of the four age groups on syllable maintenance score. The findings suggest that the performance of children for syllable maintenance is better than the correct production of words.

Radhika (2008) found that the children across age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0 years passed 60% criteria for all the twenty-four words. She also noted poorer performance by children in the age groups 2.6-3.0 and 3.0 – 3.6 years than the older age group. She also noted that few of the tasks showed complete maturation; that is praxis control was better for the older age group than the younger age group.

E. Diadochokinetic Assessment:

The performance of children in all the four age groups was analyzed for the following: (a) Accuracy, (b) consistency & (c) DDK rate

Table 8, shows the mean and SD on the performance of children across all the age groups in terms of accuracy and consistency of DDK tasks. Figure 7, shows the mean percentage scores in DDK tasks.

Table 8

Mean and SD in the performance of children across four age groups on accuracy and consistency in DDK tasks

Age groups	Accuracy			Consistency		
	Maximum Scores	Mean	SD	Maximum Scores	Mean	SD
> 4.0 - ≤ 4.6	4	4.00	0.96	16	11.63	0.66
> 4.6 - ≤ 5.0	4	3.80	0.55	16	11.63	0.99
> 5.0 - ≤ 5.6	4	3.86	0.34	16	11.80	0.40
> 5.6 - ≤ 6.0	4	3.96	0.18	16	12.00	0.00

Note. SD=Standard deviation

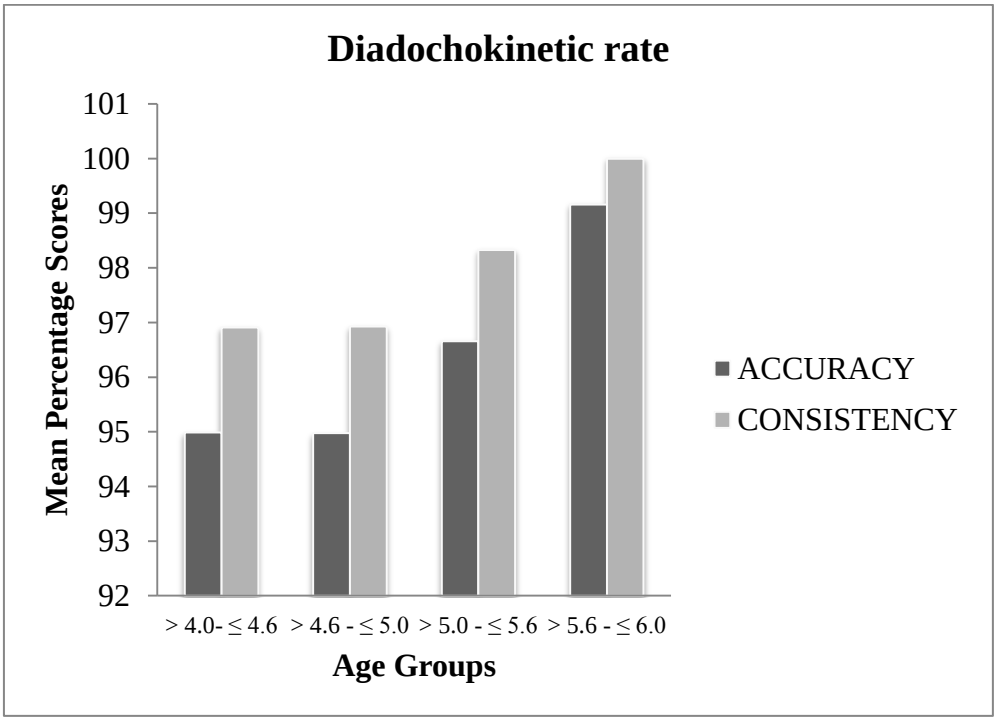


Figure 7. Mean percentage scores for four age groups on accuracy and consistency in DDK tasks.

Table 9

Mean and Standard deviation in the performance of children across the four age groups on DDK rates

Age groups (In years)	/pə pə pə /		/tə tə tə /		/kə kə kə /		/pə tə kə/	
	Max rate	Mean (SD)	Max rate	Mean (SD)	Max rate	Mean (SD)	Max rate	Mean (SD)
> 4.0 - ≤ 4.6	4.80	3.79 (0.58)	4.64	3.52 (0.57)	4.70	3.67 (0.41)	2.00	1.32 (0.35)
> 4.6 - ≤ 5.0	4.75	3.73 (0.56)	4.60	3.57 (0.53)	4.30	3.58 (0.51)	2.40	1.58 (0.40)
> 5.0 - ≤ 5.6	5.12	4.09 (0.46)	5.00	4.10 (0.39)	5.00	4.11 (0.40)	2.52	1.80 (0.34)
> 5.6 - ≤ 6.0	5.20	4.08 (0.40)	5.00	4.12 (0.34)	4.83	4.05 (0.43)	2.20	1.69 (0.29)

Note. SD=Standard deviation

(a) Analysis for accuracy

The analysis was done on /pa/, /ta/, /ka/ and /pataka/. Two-way MANOVA was carried out and there was no significant difference across gender [F (1,112) = 0.015 p > 0.05] and there was no significant difference across the four age groups for 'accuracy' [F (1,112) = 0.741 p > 0.05]. Duncan's Post Hoc Test was carried out to compare the performance across the age groups and the results showed that there was no significant difference across the age groups. The total scores for accuracy were approximately four for all the age groups. From Table 8, it is seen that the maximum and mean scores were the same across all the age groups for accuracy measure. Thus suggesting that the task is applicable for children above four years of age and a lack of developmental trend was observed. The Standard Deviation scores decreased along with age suggesting improved performance and maturation of praxis control in the older age group for accuracy of DDK measures.

(b) Analysis for Consistency:

This task was based on how the child maintains the consistency of its production of syllables in the task. The scoring was based on 0 - 3 rating scale and a total score of 12 was possible and all the four age groups scored approximately 12.. Two-way MANOVA was carried out which revealed no significant difference across gender [F (1,112) = 0.33 p > 0.05] across four age groups for 'consistency' [F (1,112) = 2.258 p > 0.05]. Duncan's Post Hoc Test was carried out to compare the parameters across the age groups which revealed a significant difference across the age groups. FromnTable 8, it is seen that the maximum score is same across all the age groups suggesting that the task is applicable for children above four years of age. The mean scores increases along with age showing a developmental trend across the four age groups. The Standard Deviation scores are least for the older age group suggesting improvement in the performance and maturation of praxis control in the older age group It also suggests that the performance of older age group is more consistent than the younger age group. In other words, the older age group performed better that younger age group.

Yaruss and Kenneth (2002) conducted a study on the accuracy of the DDK and suggested that there was no significant correlation between children's chronological age and the average number of articulation errors. The present study supports the same in terms of accuracy. Radhika (2008) found that there was no developmental trend observed in terms of both accuracy and consistency. She suggested that the performances of older age group were more mature than the younger age group.

(c) DDK Rate (Iterations/Sec)

This task was based on the number of iterations the child uttered in one second for /pa/, /ta/, /ka/ and /pataka/. Two-way MANOVA revealed no significant difference across gender /pa/ [F (1,112) = 0.3540 p > 0.05]; /ta/ [F (3,112) = 1.369 p > 0.05]; /ka/ [F (3,112) = 3.103 p > 0.05] and /pataka/ [F (3,112) = 0.338 p > 0.05] while there was significant difference across age /pa/ [F (3,112) = 4.169 p < 0.05]; /ta/ [F (3,112) = 14.58 p < 0.05]; /ka/ [F (3,112) = 11.07 p < 0.05] and /pataka/ [F (3,112) = 10.44 p < 0.05]. Duncan's Post Hoc Test was carried out to compare the performance across age groups and the results showed that there was significant difference across the age groups.

From Table 9, it is observed that the maximum scores were increased in the older age group suggesting that this task is more suitable for children above four years. The mean scores were higher for the older age group suggesting a clear developmental trend across the four age groups. The standard deviation decreased for the younger age group suggesting improvement with age for the praxis control.

F. Sentence Level Assessment:

This section included a total of ten sentences and the scoring was done in two ways,

(a) Number of Sentences Correct (NSC)

(b) Sequence Maintenance Score (SMS)

Table 10, illustrates the performance of children across four age groups on sentence level assessment. Figure 9, Shows the mean percentage scores of the performance of the children across the four age groups.

Table 10

Mean and SD of the scores obtained by children across the four age groups in sentence level assessment

Age groups (In years)	NSC			SMS		
	Maximum Scores	Mean	SD	Maximum Scores	Mean	SD
> 4.0-≤ 4.6	10	7.26	1.55	20	17.70	1.23
> 4.6-≤ 5.0	10	7.43	2.34	20	18.00	1.76
> 5.0-≤5.6	10	9.40	0.67	20	19.40	0.67
> 5.6-≤ 6.0	10	9.73	0.44	20	19.43	0.62

Note. SD=Standard deviation, NSC= Number of Sentence Correct, SMS=Sequence, Maintenance Score

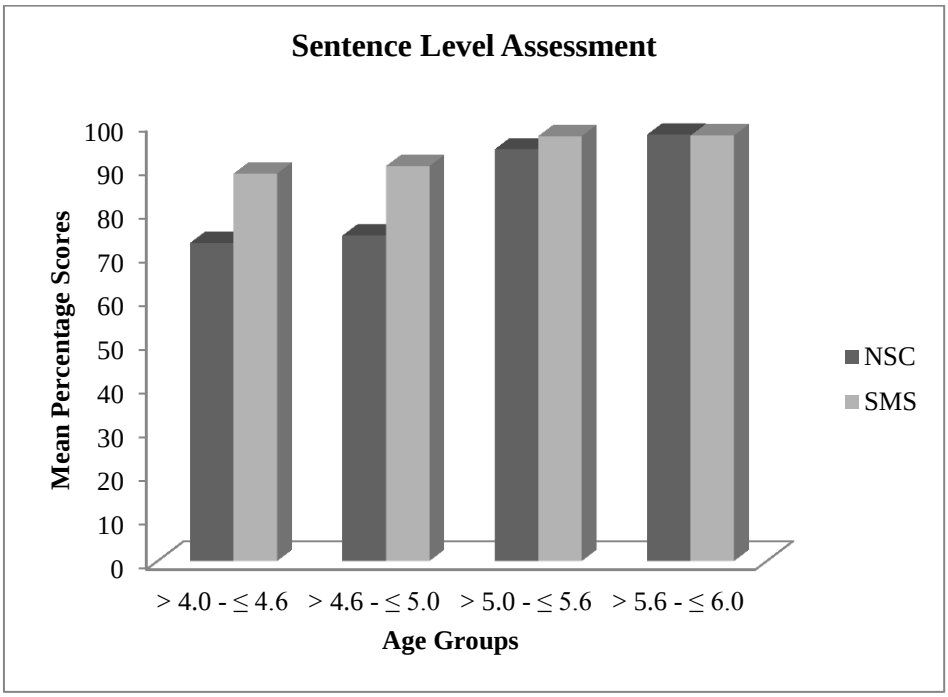


Figure 9. Mean percentage scores of four age groups on sentence level assessment

(a) Number of sentences correct (NSC):

This section included a total of ten tasks. Two-way MANOVA revealed no significant difference across gender [F (1,112) = 0.095 p > 0.05], but a significant difference across the four age groups [F (1,112) = 22.62 p < 0.05]. Duncan's Post Hoc Test was carried out to compare the parameters across the age groups and the results showed that there was a significant difference across the age groups. The children of different age groups failed to attain 60% criteria as follows: > 4.0 - ≤ 4.6 years - task 8 and task 10; > 4.6-≤ 5.0 and > 5.0 - ≤5.6 years - task 10. This is due to increase in the length of the sentence.

From Table 10, it is observed that the maximum score is the same across all the four age groups suggesting that all the tasks are applicable for children above four years of age. The mean scores increased for the older age group suggesting a developmental trend across the age groups. The Standard Deviation are variable and higher for the younger age groups and lower for the older age groups suggesting improved performance and maturation of praxis control in the older age group. Figure 5 shows the mean percentage scores of the four age groups in terms of number of sentence correctly produced. Radhika (2008) suggested that the children across all the age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0 years failed to reach 60% criteria for seven tasks. This was due to the complexity involved in the correct production of the sentences.

(b) Sequence Maintenance Score

This section included ten tasks/sentences. Two-way MANOVA revealed no significant difference across gender [F (1,112) = 0.904 p > 0.05] and there was

significant difference across the four age group [F (1,112) = 18.76 p < 0.05]. Duncan's Post Hoc test was carried out to compare the parameters across the age groups and the results showed there was significant difference across the age groups. The children in the age group > 4.0 - ≤ 4.6 years failed to reach 60% criteria for the task 10. The other three age groups could attain 60% criteria for all the tasks.

From Table 10, it was found that the mean scores increased for older age group suggesting a developmental trend across the four age groups. The Standard Deviation scores decreased for older age group suggesting improved performance and maturation of praxis control in the older age group. Figure 9 shows the percentage scores of sequence maintenance across all the four age groups.

Radhika (2008) found that children in the age groups 2.6-3.0, 3.0-3.6 and 3.6-4.0 years could reach 60% criteria for the tasks 6, 7 and 8. This was due to the increased word and syllable length. In the present study, children in the age group 4.0 – 4.6 years failed to reach 60% for the task 10. The findings of the study suggested that the performance of the children improved for the older age group than the younger age group.

(v) Conversational Assessment

The analysis was done for the 100 words corpus extracted from the recorded video sample. That is Percentage Consonant Correct (PCC) and Percentage Vowel Correct (PVC) were calculated.

Table 11, illustrates the mean scores and SD of PVC and PCC calculated across the four age groups. Figure 10, shows the percentage scores of PCC and PVC across the four age groups.

Table 11

Mean and SD of percentage consonant correct (PCC) and percentage vowel correct (PVC) obtained by children across four age group in conversational assessment

Age groups (In years)	PVC			PCC		
	Maximum Scores	Mean	SD	Maximum Scores	Mean	SD
> 4.0-≤ 4.6	100	99.47	0.72	99.3	95.66	2.64
> 4.6-≤ 5.0	100	99.91	0.24	98.3	95.47	2.18
> 5.0-≤5.6	100	100.00	0.00	99.04	97.84	1.35
> 5.6-≤ 6.0	100	100.00	0.00	99.3	97.73	0.96

Note. SD=Standard deviation, PCC=Percentage Consonant Correct, PVC= Percentage Vowel Correct

Two-way MANOVA revealed no significant difference across gender for PVC [F (1,112) = 0.00 p > 0.05] and PPC [F (1,112) = 0.01 p > 0.05] and there was significant difference across the four age groups PVC [F (1,112) = 12.59 p < 0.05] and PCC [F (1,112) = 12.59 p < 0.05].

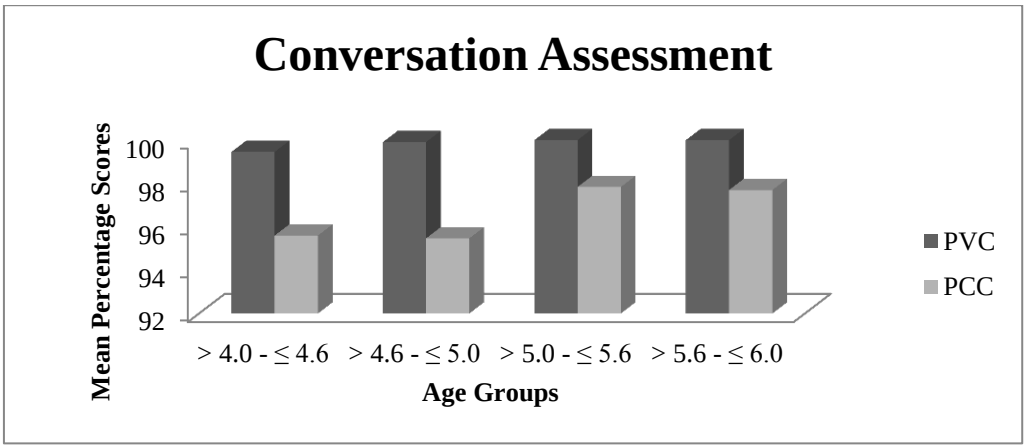


Figure 10. Mean percentage scores of four age groups on conversational assessment

Duncan's Post Hoc Test was used to compare the parameters across the age groups and the results revealed a significant difference across the age groups. From Table 11, it is seen that the maximum scores were same for all the age groups suggesting suitability of the task for children above four years of age. The mean scores increased for older age group suggesting a developmental trend in both PCC and PVC measures, but more evident in PCC measurement. The Standard Deviation scores suggested that the older age groups performed better than the younger age groups suggestive of more maturity in terms of praxis control. The current study supported the findings of Radhika (2008).

Analysis of Phonological Processes:

During the assessment, there were few phonological process observed in the sections of Word Level Praxis tests (Meaningful and Non-Meaningful Words and Relational Speech Timing Tasks). The phonological process of words were tabulated and classified into three types of errors: space, timing and whole word errors. The predominant processes that were seen in the children of this study across the groups tested included: Fronting, Backing, Depalatalization, Stopping, Deaffrication, Affrication, Degemination, Gemination, Post vocalic voicing, Prevocalic voicing, Consonant cluster reduction, Consonant deletions, Syllable deletion, Epenthesis, Reduplication, Substitution of geminate clusters for non geminate clusters. Some of the vowel deviations seen in children of the study across the age groups included: Vowel centralization and Monophthongization or dipthong reduction. One of the unusual processes seen was, Substitution of /l/ for /r/. From this information, it can be inferred that children in this age group have difficulty majorly in clusters and few

sounds like t/, /d/, /ʈ/, /ɖ/, /r/, /ʃ/, /s/, /ʅ/, /l/, /n/ are not produced accurately. As a result, substitution and distortions errors are more in children in this age group.

Intra & inter-judge reliability

In the present study, the scoring system was based on different rating scales. The scoring can vary when used by different people at different points in time. Therefore, 10% of the data (12 children), from the video recorded samples taken randomly and the responses of the participants were analyzed by another judge to establish inter-judge reliability and by the investigator after a period of four weeks from the assessment done initially to establish the intra-judge reliability. Inter and intra judge reliability was found out by reliability co-efficient alpha. Intra judge reliability yielded 94% and inter-judge reliability yielded 93.6%; suggestive of high reliability for the scoring of responses across and within the judges.

Summary

The protocol includes a total of eight sections. Most of the skills in the test and subtests in the protocol showed a developmental trend whereas in few sections there was no clear trend evident. The following section showed a clear developmental trend: isolated speech movement, NWC and SMS for meaningful words, NWC and SMS of Relational speech timing, consistency measure of DDK tasks, NWC and SMS of sentence level assessment, PCC and PVC measures of conversational assessment.

The present study helps in understanding the developmental trend for verbal praxis skills across the four age groups. The study also provides norms for the assessment of verbal praxis in children with suspected apraxia of speech (sCAS)

based on their performance for different tasks in the protocol. This will aid in the differential diagnosis of children with CAS & sAOS.

A revised protocol is presented in Appendix E based on the performance of the children across the four age groups (> 4.0 - ≤ 4.6; > 4.6- ≤ 5.0; > 5.0- ≤5.6; > 5.6- ≤ 6.0 years). The graphical representation is presented in Appendix F which is based on mean scores for the different tasks in all the sections. This helps in assessing a given child with suspected praxis deficit and comparing the scores with the scores of typical children in the four age ranges.

SUMMARY AND CONCLUSIONS

The study focused on understanding the developmental trend of verbal praxis skills in typically developing children with the age group 4.0 – 6.0 years, by using the protocol developed by Radhika (2008) for the assessment of praxis skills based on the performance of the children in different tasks of the protocol. The study also provides norms to compare the performance of children at risk for praxis deficits across all the four age groups.

CAS is a disorder which is generally difficult to differentially diagnose from other speech disorders as the characteristics overlap with other speech disorders. Therefore it is important to differentially diagnose children with childhood apraxia of speech or suspected apraxia of speech from children with other speech disorders. There is a lack of standardized scales/protocol that provides appropriate diagnostic guidelines to help in understanding the development of praxis in children. Radhika (2008) developed a protocol to assess verbal praxis in Kannada speaking typically developing children with the age group 2.6 – 4.0 years based on the protocol developed by Rupela (2008) and Banumathy (2008). The study also provided normative data for the age group 2.6 – 4.0 years. There are no scales/protocols that assess the verbal praxis development in Kannada speaking typically developing children in the age range 4 to 6 years. Therefore, this study was undertaken in order:

1. To administer the protocol developed by Radhika (2008) for the assessment of verbal praxis in Kannada language on typically developing children aged 4.0 to 6.0 years.

2. To establish norms for the different tasks in the protocol based on the performance of children in four age groups (> 4.0 - ≤ 4.6; > 4.6 - ≤ 5.0; > 5.0 - ≤ 5.6; > 5.6 - ≤ 6.0 years) of the study.

A total of 120 Kannada speaking typically developing children were included in the study. The children were subdivided into four age groups (> 4.0 - ≤ 4.6; > 4.6- ≤ 5.0; > 5.0- ≤5.6; > 5.6- ≤ 6.0) with thirty in each. The children were screened for language function, oro-motor and oro-sensory skills. Any child who exhibited language delay/deviance, oro-motor, oro-sensory and oro-structural deficits were excluded from the study.

The sections of the protocol included:

- Function of oral mechanism for speech
- Isolated speech movements
- Sequential speech movements
- Word level praxis assessment- (i) Meaningful words, (ii) Non-Meaningful words
- Relational speech timing in word context
- Sentence level assessment
- Conversational assessment

This protocol also helps in identifying different phonological processes that are classified in to space errors, timing errors and whole word errors exhibited by children across the four age groups. The protocol was administered on 120 children across the four age groups (> 4.0 - ≤ 4.6; > 4.6- ≤ 5.0; > 5.0- ≤ 5.6; > 5.6- ≤ 6.0). The responses

were recorded using a digital camcorder. The responses were obtained through imitation and transcribed using IPA. The responses in each subtest and test addressing different types of praxis skills (oral and verbal) were rated by the investigators using different rating scales for each section of the protocol. A criteria of maximum 60% of scores obtained by the children in the group was considered a indicative of acquisition/development of the skill. Statistical analysis was done using the SPSS (version 18.0). The maximum and mean scores with standard deviations of the group was computed for each skill tested. Intra and inter-judge reliability was run on ten percent of the data as the protocol involved rating scales. The results showed high intra and inter-reliability.

The salient findings from the study is summarized

The protocol included a total of eight sections. Most of the sections in the protocol showed a developmental trend whereas few sections did not show a clear developmental trend. The following section showed a clear developmental trend in the following: isolated speech movement, NWC and SMS for meaningful words, NWC and SMS of Relational speech timing, consistency measure of DDK tasks, NWC and SMS of sentence level assessment, PCC and PVC measures of conversational assessment. The protocol provides the normative data for the given age groups and helps in the differential diagnosis of children who are at risk for praxis breakdown. Appendix A shows the mean scores of the four age groups. The score of a given Kannada speaking child with suspected praxis deficit can be compared with the mean score obtained by the Kannada speaking typical children listed in the Appendix A. A score below the score of typical group would serve as an indicator to identify children with sAOS.

Limitations of the study:

- During the assessment of the protocol, the responses were recorded by instructing the child to imitate after the investigator by seeing the face and a model was not provided. This could have led to variations in the child's response.
- To obtain standardized norm, the protocol needs to be administered on larger group of children.

Future directions:

1. The protocol can be standardized on children of older age groups (above 6 years of age) as the studies suggest that verbal praxis skills are reported to continue to mature upto 8 years.
2. Protocol can be translated and developed in other Indian languages to aid in early intervention and differential diagnosis of children with suspected apraxia of speech.

REFERENCES

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

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

Banumathy, N. (2004). *Behavioural correlates of speech processing in normal speakers under delayed auditory feedback*. Unpublished Masters Dissertation, University of Mysore.

Banumathy, N. (2008). *Investigation of subgroups in Developmental Apraxia of Speech*. published Thesis, University of Mysore.

Banu.T. (1977). *Articulatory acquisition in Kannada: A study of normal children (3 – 6.6 years).* Unpublished master's dissertation, University of Mysore. Mysore.

Blakely, R. W. (2001). *Screening Test for Developmental Apraxia of Speech: Examiner's Manual*. Pro-ed.

Bartle-Meyer, C. J., Gooze, E. J. & Murdoch, B. E. (2009). Kinematic Investigation Of Lingual Movement In Words Of Increasing Length In Acquired Apraxia Of Speech. *Clinical Linguistics & Phonetics, 23,* 93–121.

Byrd, K., & Cooper, E, B. (1989). Praxic speech characteristics in stuttering, developmentally apraxic, and normal speaking children. *Journal of fluency disorder*, *14*, 215-229.

Davis, B, L., Jakielski, K, J., & Marquardt, P, Q. (1998). Developmental apraxia of speech: Determiners of differential diagnosis. *Clinical linguistics & phonetics*, *12*, 25-45.

Fidler, D. J., Hepburn, S. L., Mankin, G., & Rogers, S. J. (2005). Praxis skills in young children with Down syndrome, other developmental disabilities, and typically developing children. *American Journal of Occupational Therapy, 59,* 129–138.

Fish, M. (2011). *Here's how to treat Childhood Apraxia of Speech*, Plural publishing, Inc.

Forest, K. (2003). Diagnostic criteria of Developmental Apraxia of Speech used by clinical Speech-Language Pathologists. *American Journal of Speech-Language Pathology, 12,* 376-380

Geetha, Y. V. (2007). *Assessment checklist for speech and language skills*. Unpublished project report under AIISH research fund, AIISH, Mysore.

Goffman, L., & Smith, A. (1999). Development and differentiation of speech movement patterns. *Human Perception and Performance, 25,* 1–12.

Green, J. R., Moore, C. A., Higashikawa, M., & Steeve, R. W. (2000). The physiological development of speech motor control: Lip and jaw coordination. *Journal of Speech, Language, and Hearing Research, 43*, 239–255.

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.

Groenen, P., Maassen, B., Crul, T., & Thoonen, G. (1996). The specific relation between perception and production errors for place of articulation in developmental apraxia of speech. *Journal of Speech and Hearing Reasearch, 39*, 468-82

Guyette, T., & Diedrich, W. (1981). A critical review of developmental apraxia of speech. In N. Lass (Ed.), Speech and language: *Advances in basic research and practice*, *5* (pp.1-49). New York: Academic Press

Hall, P. K., Jordan, L. S & Robin, D. A. (1993). *Developmental Apraxia of speech*. PRO-ED, Inc.

Hall, P., Jordan, L., & Robin, D. (2007). *Developmental Apraxia of Speech* (2nd ed.). Austin, TX: Pro-E

Harrington, J., & Tabian, M. (2006). *Speech Motor Control complexity. Speech production, models, phonetic process and techniques*. 13-26.

Hayden, D, A. (1994). Differential Diagnosis of Motor Speech Dysfunction in Children. *Clinical communication disorder*, *4*, 119-141.

Hayden, D., & Square, P. (1999). *Verbal Motor Production Assessment for children*. San Antonio, Tx: The psychological corporation.

Horwitz, S. J. (1984*).* Neurological findings in developmental verbal apraxia. *Seminars in speech and language, 5,* 111-118.

Kauffman, N. (1995). Super Duper publication. Retrieved August 15, 2007 http://www.superduperinc.com/index.html

Kent, R. D. (1976). Anatomical and Neuromuscular maturation of the speech mechanism: Evidence from Acoustic studies. *Journal of Speech and Hearing Research, 19*, 422-447.

Kent, R. D. (2000). Research on speech motor control and its disorders: A review and prospective. *Journal of communication disorders, 33*, 391-428.

Kools, J. A., & Tweedie, D. (1975). Development of praxis in children. *Percept Mot Skills, 40*, 11-19.

Kumin L. (2006). Speech intelligibility and childhood verbal apraxia in children with Down syndrome. *Down syndrome Research and Practice, 10,* 10-22.

Maassen, B., Kent, R., Peters, H., Lieshout, P. V., & Hulstijn, W. (2004). *Speech motor control*. Oxford University Press.

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., Frank H, G., & Brumberg, G. J. (2009). Computational Neural Modeling of Speech Motor Control in Childhood Apraxia of Speech (CAS). *Journal of Speech, Language, and Hearing Research, 51,* 1595–1609.

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., 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

May-Benson, T. A., & Cermak, S. A. (2007). Development of an assessment for ideational praxis. *American Journal of Occupational Therapy, 61,* 148–153.

Miller, J., Rosin, P., & Netsell, L. (1979). *The Acquisition of Speech Motor Control : A perspective direction for research*. In Netsell, R, Neurobiologic view of speech production and the Dysarthrias, 1-31. San Diego, California : College Hill Press

Munson, B., Bjorum, B, M., & Windsor, J. (2003). Acoustic and Perceptual Correlates of Stress in Nonwords Produced by Children With Suspected Developmental Apraxia of Speech and Children With Phonological Disorder. *Journal of Speech, Language, and Hearing Research*, *46*, 189–202

Murdoch BE, Attard MD, Ozanne AE, Stokes PD.(1995). Impaired tongue strength and endurance in developmental verbal dyspraxia: *A physiological analysis. European Journal of Disorders of Communication.30*:51–64

Pascal H. H. M., Lieshout, V., Bose, A., Squarel, P. A & Steele, C. M. (2007). Speech Motor Control in fluent and dysfluent speech production of an individual with apraxia of speech and broca's aphasia. *Clinical Linguistics & Phonetics, 21*, 59–188.

Peter, B., & Stoel-Gammon, C. (2005). Timing errors in two children with suspected childhood apraxia of speech (sCAS) during speech and music-related tasks. *Cinical Linguistics & Phonetics*, *19*, 67–87.

Prathima, s. (2009). *Articulatory acquisition in kannada speaking urban children: 3-4 years.* Unpublished dissertation submitted to university of Mysore, Mysore.

Radhika, S. (2008). *Protocol for Appraisal of verbal praxis in typically developing children (2.6-4.0years).* Unpublished master's dissertation, University of Mysore.

Robbins, J., & Klee, T. (1987). Clinical Assessment of Oropharyngeal Motor Development in Young Children. *Journal of Speech and Hearing Disorders, 52*, 271-277.

Robin, D. A., Somodi, L. B., Luschei, E. S. (1991). Measurement of tongue strength and endurance in normal and articulation disordered subjects. In: Moore C, Yorkston, K. M., Beukelman, D. R., editors.Dysarthria and apraxia of speech: *Perspectives on management. Baltimore: Paul H. Brookes*, 173–184.

Rogers, M. A. (1997). The Vowel lengthening exaggeration effect in speakers with Apraxia of Speech : compensation, artifact or primacy deficit? *Aphasiology, 11*, 433-445.

Rosenbek, J.C., & Wertz, R.T. (1972). A review of 50 cases of developmental apraxia of speech. *Language, Speech, and Hearing Services in Schools, 3*, 23-33.

Sharkey, S.G., & Folking, J.W. (1985). Variability of lip and jaw movements in children and adults: Implications for the development of speech motor control. *Journal of speech and Hearing Reasearch, 28,* 8-15.

Sharkins, S. G., & Folkins, J. W. (1985). Variability of Lip and Jaw Movements in Children and Adults. *Journal of Speech and Hearing Research , 28,* 8-15

Shriberg, L. D., Aram, D. M., & Kwiatkowski, J. (1997). Developmental apraxia of speech: I. descriptive and theoretical perspectives. *Journal of Speech Language and Hearing Research, 40,* 273–285.

Shriberg, L. D., & Campbell, T. F. (Eds.). (2003). Proceedings of the 2002, Childhood Apraxia of Speech Research Symposium. Carlsbad, CA: The Hendrix Foundation.

Shriberg, L. D., Kwiatkowski, J., & Rasmussen, C. (1990). The *Prosody Voice Screening Profile*. Tucson, AZ: Communication Skill Builders

Smith, A., & Goffman, L. (1998). Stability and patterning of speech movement sequences in children and adults. *Journal of Speech, Language, and Hearing Research, 41,* 18–30.

Smith, A., Goffman, L., Zelaznik, H., Ying, G., & McGillem, C. (1995). Spatiotemporal stability and patterning of speech movement sequences. *Experimental Brain Research, 104,* 493–501.

Smith, B. L., & McLean-Muse, A. (1986). Articulatory movement characteristics of labial consonant production by children. *Journal of the Acoustical Society of America, 80,* 1321–1327.

Smith, A., Johnson, M., McGillem, C., & Goffman, L. (2000). On the assessment of stability and patterning of speech movements. *Journal of Speech, Language, and Hearing Research, 43,* 277–286.

Smith, A., & Zelaznik, H. N. (2004). Development of functional synergies for speech motor coordination in childhood and adolescence. *Developmental Psychobiology*, *45*, 22–33.

Stackhouse, J. (1992). Developmental verbal dyspraxia I: A review and critique. *European Journal of Disorders of Communication, 27,* 19–34.

Strand, E.A. & McNeil, M. R . (1996). Effects of length and linguistic complexity on temporal
acoustic measures in Apraxia of Speech. *Journal of Speech and Hearing Research, 39,*
1018-1033.

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,* Washington D.C

Sutherl, D., & Gillon, G. T. (2007). Development of phonological representations and phonological awareness in children with Speech impairment. *International Journal of language and communication disorders, 42*, 229-250.

Terband, H., & Maassen, B. (2010). Speech Motor Development in Childhood Apraxia of Speech: Generating Testable Hypotheses by Neurocomputational Modeling. *Folia Phoniatrica Logopedica*, *62*, 134–142.

Thoonen, G., Maassen, B., Gabreels, F., Schreuder R., and Swart, B. (1996). The integrated use of maximum performance tasks in differential diagnosis evaluation among children with motor speech disorders. *Clinical Linguistics and Phonetics, 10*, 311-366.

Thoonen, G., Maassen, B., Gabreels, F., Schreuder R., and Swart, B. (1997). Towards a standardised assessment procedure for developmental apraxia of speech. *International Journal of language and communication disorders, 32*, 37-60

Walsh, B., & Smith, A. (2002). Articulatory movements in adolescents: Evidence for protracted development of speech motor control processes. *Journal of Speech, Language, and Hearing Research, 45*, 1119–1133.

Williamson, G. G., Anzalone, M. E., & Hanft, B. E. (2000). *Assessment of Sensory Processing, Praxis, and Motor Performance*. 155-184.

Yaruss, J. S., & Logan, K. J. (2002). Evaluating rate, accuracy, and fluency of young children's diadochokinetic productions: a preliminary investigation. *Journal of Fluency Disorders, 27*, 65-85.

Yan (2007). *A physiologic investigation of speech motor development*, School of Health and Rehabilitation Sciences, University of Queensland.

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.

Zharkova, N., Hewlett, WilliaN., & Hardcastle, J. M. (2011). Coarticulation as an Indicator of Speech Motor Control Development in Children: An Ultrasound Study. *Motor Control, 15*, 118-140.

APPENDIX - A

PROTOCOL FOR APPRAISAL OF VERBAL PRAXIS IN TYPICALLY DEVELOPING CHILDREN (4.0 - 6.0 YEARS)

Name:

Date:

Age/Gender:

Education:

School:

Language age:

Other relevant information:

I. FUNCTION OF THE ORAL MECHANISM FOR SPEECH:

Instructions: The child is instructed to imitate the following activities after the investigator.

Stimuli:

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

Scoring: Scores of 0 - 1 is offered based on the adequacy / inadequacy of the performance. A score of '0' is given for inadequate performance and a score of '1' is given for adequate performance.

II. VERBAL PRAXIS TOOL

A. ISOLATED SPEECH MOVEMENTS:

Instructions: The child is instructed to imitate the following vowels, consonants and syllables after the investigator.

Stimuli:

Action	***Accuracy***	***Repetition***	***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/			
Tongue movement			
11. Say /tə/,			
12. Say /də/,			
13. Say 'n…'			
14. Say 'l...'			
15. Say 's…'			
16. Say /kə/,			
17. Say /gə/			
18. Say /Tə/,			
19. Say /ɖə/			
20. Say /ə/			
21. Say /lə/			
22. Say /ʧə/			
23. Say /rə/			
24. Say 'shh…'			

Scoring: Scores of 0 to 3 is offered based on the accuracy of speech movements and depending on whether repetitions or cues are given to the child. It may be noted that additional cues given if the child is not paying attention & /or not compliant should be disregarded in scoring.

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 repititions

B. SEQUENTIAL SPEECH MOVEMENTS:

Instructions: The child is instructed to imitate the following sequences of vowels and consonants .If the child is able to do this, then the child is instructed to imitate each sequence three times each followed by the investigator. A maximum of two attempts can be given to the child for the correct production.
Stimuli:

Sl. No	***Action***	***Response***	***No. of trials/times repeated***	***MCS***	***SMS***
1	a-u				
2	o - i				
3	m-u				
4	i-u-a				
5	o-m-i				
6	a-m-u				
7	u-i-a				

Scoring:
Motor control score (MCS): Scores of 0-2 is offered based on the appropriateness of movements. The number of times / trials the actions was repeated can be noted down.
Motor control score (MCS):
2- All movements are precise
1- One of the movement 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): Scores of 0-2 is offered based on the appropriate maintenance for the sequence (i.e. the correct order in which, the sequences of vowels, consonants are repeated). The number of times / trials the actions was repeated can be noted down.
Sequence maintenance score (SMS):
2- Repeats all phonemes correctly
1- Repeats 2 out of 3 sequences correctly or repeats the phonemes 5 or 6 times.
0- Repeats one out of 3 sequences correctly or repeats the phoneme sequence more than 6 times

C. WORD LEVEL PRAXIS ASSESSMENT:

(i) MEANINGFUL WORDS:

Instructions: The child is instructed to repeat the following words after the investigator. A maximum of two attempts can be given to the child for the correct production. The responses have to be transcribed and scored accordingly.

Target	***Response***	***Phonological Errors***			***Dysfluencies***	***Weak presision***	**Score (NWC)**	***Sequence score (SMS)***
		SE	*TE*	*WWE*				
DNC								
təlɛ								
Sirɛ								
mənɛ								
Sebu								
najı								
DWC								
bɛkkʊ								
pɛnnʊ								
ʧʰətrı								
təʈʈɛ								
Surja								
TNC								
bagılʊ								
hʊɖʊgı								
kıʈəkı								
ʧəməʧa								
kudəlʊ								
TWC								
rəŋgolı								
daɭımbɛ							* $	
pʊstəkə								
ʧəppəlı								
iruɭlı							$	

Target	***Response***	***Phonological Errors***			***Dysfluencies***	***Weak presision***	**Score (NWC)**	***Sequence score (SMS)***
		SE	*TE*	*WWE*				
MNC								
ərəmənɛ								
ədɻgemənɛ								
batʃənɻgɛ								
gədɻjara								
gaɭɪpətə								
MWC								
kənnədəka								
baɭɛhənɳŋʊ								
devəst^{h}ana								
alu:gədɖɛ								
tɛŋgɪnəkaji								
D2C								
krɪʂɳa							* $	
drɪçjə							* $	
prəçnɛ							* $	
swətʃʧ^{h}ə								
drakʂi							* $	
T2C								
vjəvəst^{h}ɛ							* $ • ♦	* $ • ♦
prart^{h}əne							* $ •	
brəhmərʂi							* $ • ♦	*
svərgəst^{h}ə							* $ • ♦	
prəkʂʊbdatɛ							* $ • ♦	* $ •

Note:

*- Not applicable for children of 4.0 - 4.6 years
$- Not applicable for children of 4.6 -5.0 years
•- Not applicable for children of 5.0 -5.6 years
♦- Not applicable for children of 5.6 - 6.0 years

The target words increase in syllabic complexity from:

DNC- Di-syllable **No** cluster (with out cluster)
DWC- Dis-syllabic with cluster
TNC- Tri-syllabic No Cluster
TWC- Tri-syllabic with cluster
MNC- Multisyllabic No Cluster
MWC- Multisyllabic with cluster
D2C- Disyllabic with two clusters
T2C- Trisyllabic with two clusters

The following types of errors are noted after transcribing the responses.
Space errors: Fronting, backing and vowel deviations including vowel prolongation, vowel centralization, monophthongization, diphthongization.
Timing errors: voicing errors, affrication, deaffrication, nasalization, denasalization,gemination and consonant cluster reduction.
Whole word errors: sequencing errors like reduplication, consonant harmony, migration,metathesis, epenthesis, initial consonant deletion, final consonant deletion, initial, medial and final syllable deletions (mention the number of syllables deleted).

Dysfluencies: repetitive production of speech sounds, hesitations, pauses, secondaries.

Scoring (NWC- No. of words correct):
Scores of 0-1 is offered based on the correct production of the words.
Sequence maintenance score (SMS): Scoring of 0-2 is offered based on the appropriate maintenance of the sequence of syllables.
Sequence maintenance score for 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, if consonant cluster reduction / deletion, consonant harmony, vowel harmony is present.
0- Repeats only one syllable or does not repeat any syllable.

If the child does not respond, mark as No Response (NR) and score 0

Sequence maintenance score for 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, consonant cluster reduction / deletion, consonant harmony, vowel harmony.
0- Repeats one syllable correctly or does not repeat any syllable in the correct order

If the child does not respond, mark as No Response (NR) and score 0. The scores were not reduced for consonant / vowel substitution unless where consonant/vowel harmony occured as repetition of syllables and deletion or reduction of syllables occured as a result of consonant cluster reduction or deletion.

(ii) NON-MEANINGFUL WORDS:

Instructions: The child is instructed to repeat the following words after the investigator. A maximum of two attempts can be given to the child for the correct production. The responses have to be transcribed and scored accordingly.

Stimuli:

Target	***Response***	***Phonological Errors***			***Dysfluencies***	***Weak presision***	**Score (NWC)**	***Sequence score (SMS)***
		SE	*TE*	*WWE*				
Set A (I)								
pəkʊ								
nɪtɛ								
gɪba								
dɪbʊ								
lʊʈɛ								
Set A (II)								
pɪʈəbɪ								
nələta								
tɪpʊɖʊ								
dəmətə								
dəɖolʊ							*	
Set B (I)								
rəɪsa								
çɛʃo							* $ • ♦	
gɪmbʊ								
trəjjo							* $	
pləŋgo								
Set B (II)								
kɛtrəjo							* $	
səʊdʒɪ								
rəŋgəʃʊ								
çɔkkəmbɛ							$	
strəgodʒʊ							* $ • ♦	* $

Note:
*- Not applicable for children of 4.0 - 4.6 years
$- Not applicable for children of 4.6 -5.0 years
•- Not applicable for children of 5.0 -5.6 years
♦- Not applicable for children of 5.6 - 6.0 years

The following types of errors are noted after transcribing the responses.

Space errors: Fronting, backing and vowel deviations including vowel prolongation, vowel centralization, monophthongization, diphthongization.
Timing errors: voicing errors, affrication, deaffrication, nasalization, denasalization, gemination and consonant cluster reduction.
Whole word errors: sequencing errors like reduplication, consonant harmony, migration,metathesis, epenthesis, initial consonant deletion, final consonant deletion, initial, medial and final syllable deletions (mention the number of syllables deleted).

Dysfluencies: repetitive production of speech sounds, hesitations, pauses, secondaries

Scoring (NWC):

Scores of 0-1 is offered based on the correct production of the words
Sequence maintenance score (SMS): Scoring of 0-2 is offered based on the appropriate maintenance of the sequence of syllables.

Sequence maintenance score for 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, if consonant cluster reduction / deletion, consonant harmony, vowel harmony is present.
0- Repeats only one syllable or does not repeat any syllable.

If the child does not respond, mark as No Response (NR) and score 0

Sequence maintenance score for 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, consonant cluster reduction / deletion, consonant harmony, vowel harmony.
0- Repeats one syllable correctly or does not repeat any syllable in the correct order

If the child does not respond, mark as No Response (NR) and score 0. The scores were not reduced for consonant / vowel substitution unless where consonant/vowel harmony occured as repetition of syllables and deletion or reduction of syllables occured as a result of consonant cluster reduction or deletion.

E. RELATIONAL SPEECH TIMING IN WORD CONTEXT:

Instructions: The child is instructed to repeat the following words after the investigator. A maximum of two attempts can be given to the child for the correct production. The responses have to be transcribed and scored accordingly.

Stimuli:

Set No	***Type of Base word (BW)***	***Stimuli 1: Baseword (RST-I)***			***Stimuli 2: Baseword (RST-II)***			***Stimuli 3: Baseword (RST-III)***		
			Score			***Score***			***Score***	
			NWC	***SMS***		***NCW***	***SMS***		***NWC***	***SMS***
1	***Monosyllable***	/ba:/			/ba:gi/			/ba:gilu/		
2	***Monosyllable***	/ta:/			/ta:/			/ta:ta/		
3	***Monosyllable***	/ba:/			/ba:la/			/ba:laka/		
4	***Monosyllable***	/bhu/			/bhu:mi/			/bhu:mika/		
5	***Bisyllable***	/kara/			/karaga/			/karagaṭa/		
6	***Bisyllable***	/gaaja/			/gaajaka/			/gaajakaru/		
7	***Bisyllable***	/dziva/			/dzi:vana/			/dzi:vanadi/		
8	***Bisyllable***	/sara/			/saraḻa/	*$		/saraḻate/	*$♦	*$

Note:

*- Not applicable for children of 4.0 - 4.6 years
$- Not applicable for children of 4.6 -5.0 years
•- Not applicable for children of 5.0 -5.6 years
♦- Not applicable for children of 5.6 - 6.0 years

Scoring (NCW):
A score of 0-1 is offered based on the correct production of the words.

Sequence maintenance score (SMS): Scoring of 0-2 is offered based on the appropriate maintenance of the sequence of syllables.

Sequence maintenance score for 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, if consonant cluster reduction / deletion, consonant harmony, vowel harmony is present.
0- Repeats only one syllable or does not repeat any syllable.

If the child does not respond, mark as No response (NR) and score 0

Sequence maintenance score for 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, consonant cluster reduction / deletion, consonant harmony, vowel harmony.

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

III. DIADOCHOKINETIC ASSESSMENT:

Instructions:
The child is instructed to repeat /pə-pə-pə/, /ţə-ţə - ţə/, /kə - kə - kə/, /pə -ţə-kə/as fast as possible. The task is demonstrated by the investigator and the child isasked to imitate the same. The duration of the trial has to be noted down.

Stimuli:

Sl. No	*Stimulus*	*No. of iterations*	*Duration of trial (in sec)*	*DDK (it/sec)*	*Attempts*	*Accuracy*	*Consistency*
1	/pə-pə-pə/						
2	/ţə -ţə-ţə/						
3	/kə-kə-kə/						
4	/pə-ţə-kə/						

A minimum often iterations within two attempts is required for the diadochokinetic assessment .If a child is able to perform this, then the sample is considered for the following analysis.

- *Attempts:*

The number of attempts, the child took to produce a minimum often iterations can be noted down. It is a qualitative measure. No scoring is done for this

- *Accuracy:*

Responses of all the subjects were rated for accuracy with respect to articulation.

Scoring: Scores of 1 is offered for the accurate production of the sequences & 0 for inaccurate production of the sequence.

- *Consistency:*

The first four iterations are selected from the sample and these iterations were considered for scoring.

Scoring: ***Scores of 0-3 are offered based on the consistency of production of the first three iterations***

- ***Consistency scores:***
  - 3- Consistent repetition, no change from 1 repetition to next.
  - 2- Three of the four repetitions are consistently repeated.
  - 1- Two of four repetitions are consistently repeated.
  - 0- All repetitions are different from one another.

- ***DDK rate:***

A minimum of ten iterations are considered for calculating diadochokinetic rate (DDK rate).

DDK rate = Total number of iterations (Iterations/second or it/sec)
Duration of trials

IV. SENTENCE LEVEL ASSESSMENT:

Instructions: The child is instructed to repeat the following sentences after the investigator. A maximum of two attempts can be given to the child for the correct production.

Stimuli:

Stimuli	*Response*	*Score (NSC)*	*Sequence maintenance Score (SMS)*
1.ıllı ba			
2.ədu mərə			
3.nan bərıjəlla			
4.nənge ʤvəra ıdɛ		*	
5.a karʊ hogta ıdɛ			
6.skuləlli ʧənnag odbekʊ			
7.məisurəllı ərməne ıdɛ			
8.gaɭıpəʈə məgu kəijəllıdɛ		*	
9.nəməɳɳə kafikʊɖıta ıddarɛ			
10.nɛnnɛ əmma nənge məısurpak maɖkƆʈru		* $ •	*

Note

*- Not applicable for children of 4.0 - 4.6 years
$- Not applicable for children of 4.6 -5.0 years
•- Not applicable for children of 5.0 -5.6 years
♦- Not applicable for children of 5.6 - 6.0 years

Scoring (NSC- No. of sentences correct):
A score of 0-1 is offered for the correct production of the sentences. A score of 1 is offered for the correct production of the sentence and score of 0 for is offered for incorrect production of the sentence.
Sequence maintenance score (SMS):
Scores of 0-2 are offered based on the maintenance of correct sequencing of words in sentences.

2- All the words are in the exact order or position/ child uses a consistent phoneme

substitution

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 does not respond, mark as No Response (NR) and score 0

V. CONVERSATIONAL ASSESSMENT:

Instructions:

The conversational speech sample of around 100 words is recorded by asking the child general questions about his name, friends, family, house, school etc. The following errors are calculated.

1. Consonant Errors:

For calculating Percentage consonant correct (PCC) the following data is excluded from the analysis:

- Unintelligible and partially intelligible utterances
- Vowels
- Consonants, which are repeated for the third time or more on repetition of the same word, if the pronunciation did not change. But if the pronunciation changed all the consonants are included for scoring.

The following were considered when the sample was analyzed for consonant errors.

- Dialectal changes, casual speech pronunciations and allophonic variations were not scored as incorrect.
- Consonant deletions are scored as incorrect
- Consonant substitutions are scored as incorrect
- Partial voicing are scored as incorrect
- Distortions are scored as incorrect
- Additions of consonants are scored as incorrect

Calculate the 'Percentage of Consonants Correct' (PCC) using the formula:

$$PCC = \frac{\text{Total number of correct consonants}}{\text{Total number of consonants attempted}} \times 100$$

2. Vowel errors:

For calculating Percentage vowel correct (PVC) the following data is excluded from the analysis.

- Unintelligible and partially intelligible utterances
- Consonants
- Vowels which are repeated for the third time or more on the same word, if the pronunciation did not change, but if pronunciation changed, all the vowels are included for scoring

The errors in the remaining data are identified using the following criteria:

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

- Vowel deletions are scored as incorrect.
- Vowel substitutions are scored as incorrect.
- Distortions are scored as incorrect.
- Additions of vowels are scored as incorrect.

The total number of vowel errors is tallied from the transcribed samples and the percentage of vowels correct (PVC) will be calculated as follows:

$$PVC = \frac{\text{Total number of correct vowels}}{\text{Total number of vowels attempted}} \times 100$$

Transcribed sample:

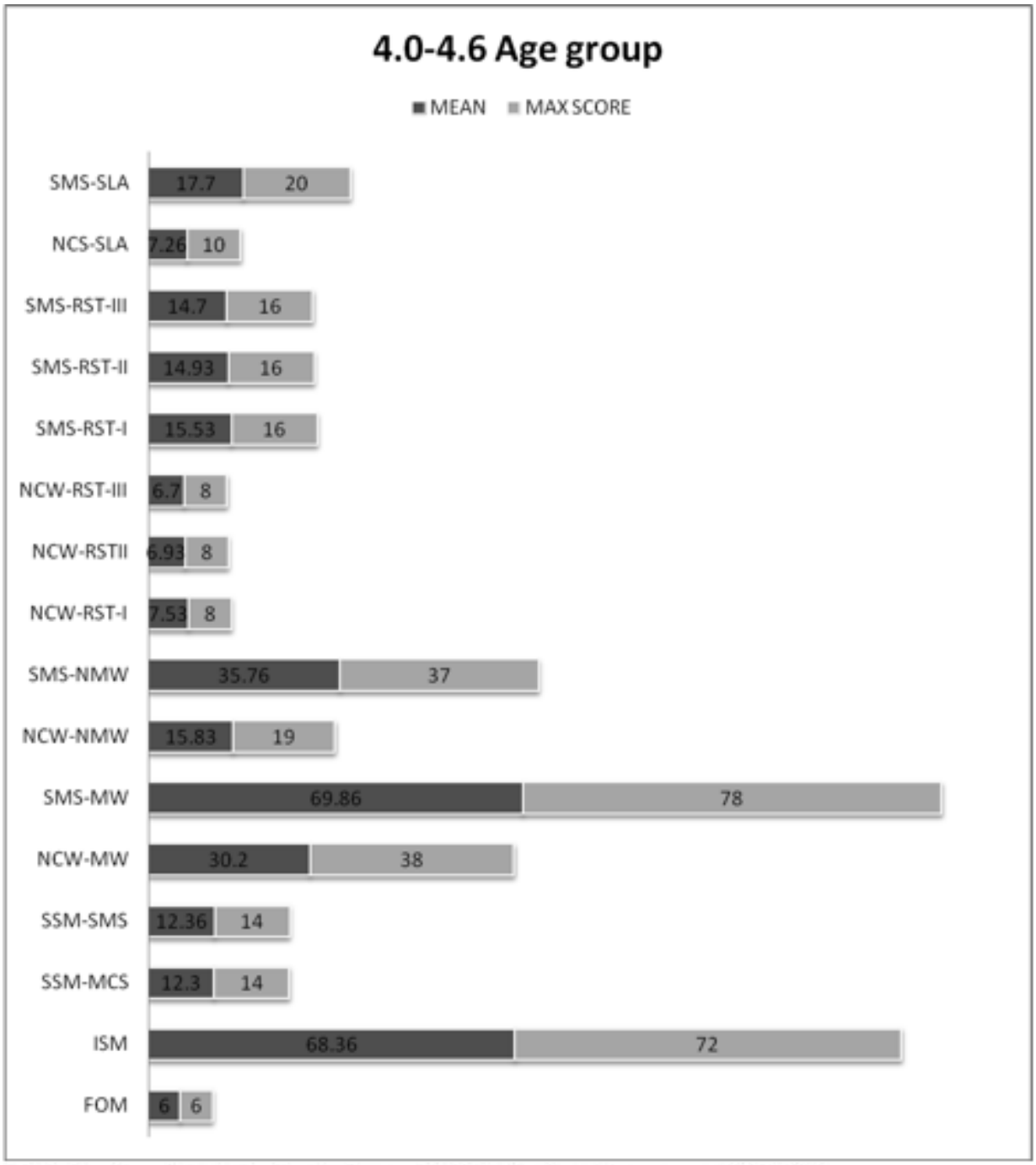
APPENDIX - B

Four graphs are given below to help the investigator in interpreting the results of the protocol. The graphs are given separately for children of the three age groups (4.0 - 4.6, 4.6 - 5.0, 5.0 - 5.6 & 5.6 – 6.0). The graphs should be used only after administering the protocol given in Appendix E on a given child.

Representation of the mean scores of a given child with reference to established norms:

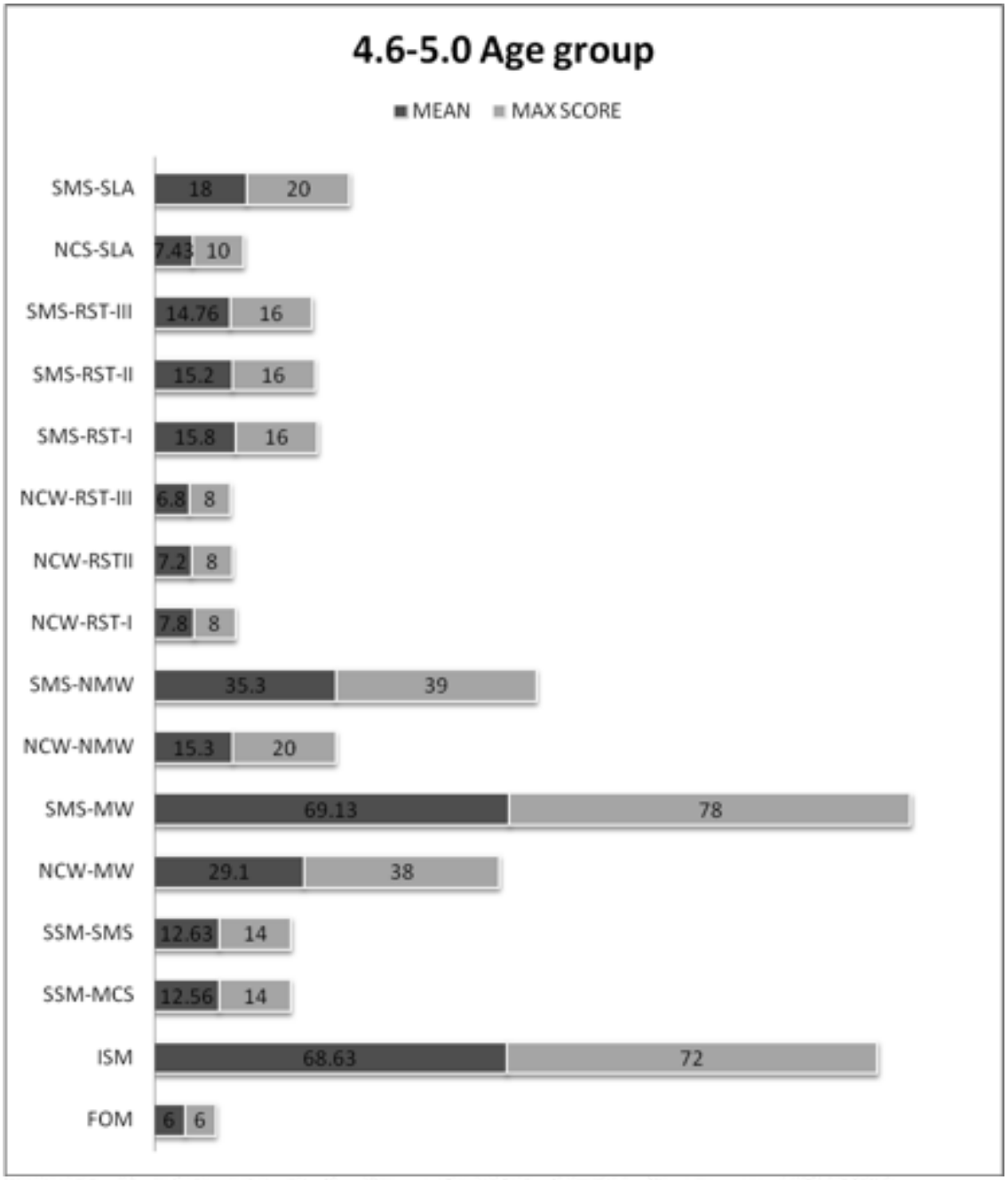
The x axis represents the number of tasks and the y axis represents different sections used in the protocol. The graph indicates the mean scores and the maximum scores and the values are written on the bars. The values on the darker shade are the mean scores and the values on the lighter shade are the maximum scores. The mean score is indicated by a vertical line placed in the horizontal bars representing various tasks. The investigator can interpret whether the child is performing optimally or not by matching the scores obtained by the child with the mean scores indicated in this graph and understand whether the child is performing at or below average / above average levels on the protocol. A score on the vertical line of a horizontal bar for a task represents average performance (matching the mean of the group). A score which falls to the left of the vertical line represents below average performance for the task and a score which falls to the right of the vertical line represents above average performance for the task. A child whose performance falls in the below average performance range (i.e to the left side of the vertical line) could be at risk for praxis breakdown. Thus the graph helps in identifying suspected apraxia of speech (sCAS) in young Kannada speaking children in the age range of 4.0 - 6.0 years.

PERFORMANCE GRAPH FOR 4.0-4.6 YEARS



* **FOM**- function of the oral mechanism for speech, **ISM**- Isolated speech movements, **SSM-MSC**- sequential speech movements; motor control score, **SSM- SMS**- sequential speech movements- sequence maintenance score, **NCW-NW**- number of correct words- meaningful words, **SMS-MW**- sequential maintenance score- meaningful words, **NCW-NMW**- number of correct words- non meaningful words, **SMS-NMW**- sequential maintenance score- non meaningful words, **NCW-RST I**- number of correct words- relational words speech timing I, **NCW-RST-II**- number of correct words- relational words speech timing II, **NCW-RST III**- number of correct words- relational words speech timing III, **SMS-RST**- sequence maintenance score- relational words speech timing, **NCS-SLA**- number of correct sentence- sentence level assessment, **SMS-SLA**- sequence maintenance score- sentence level assessment

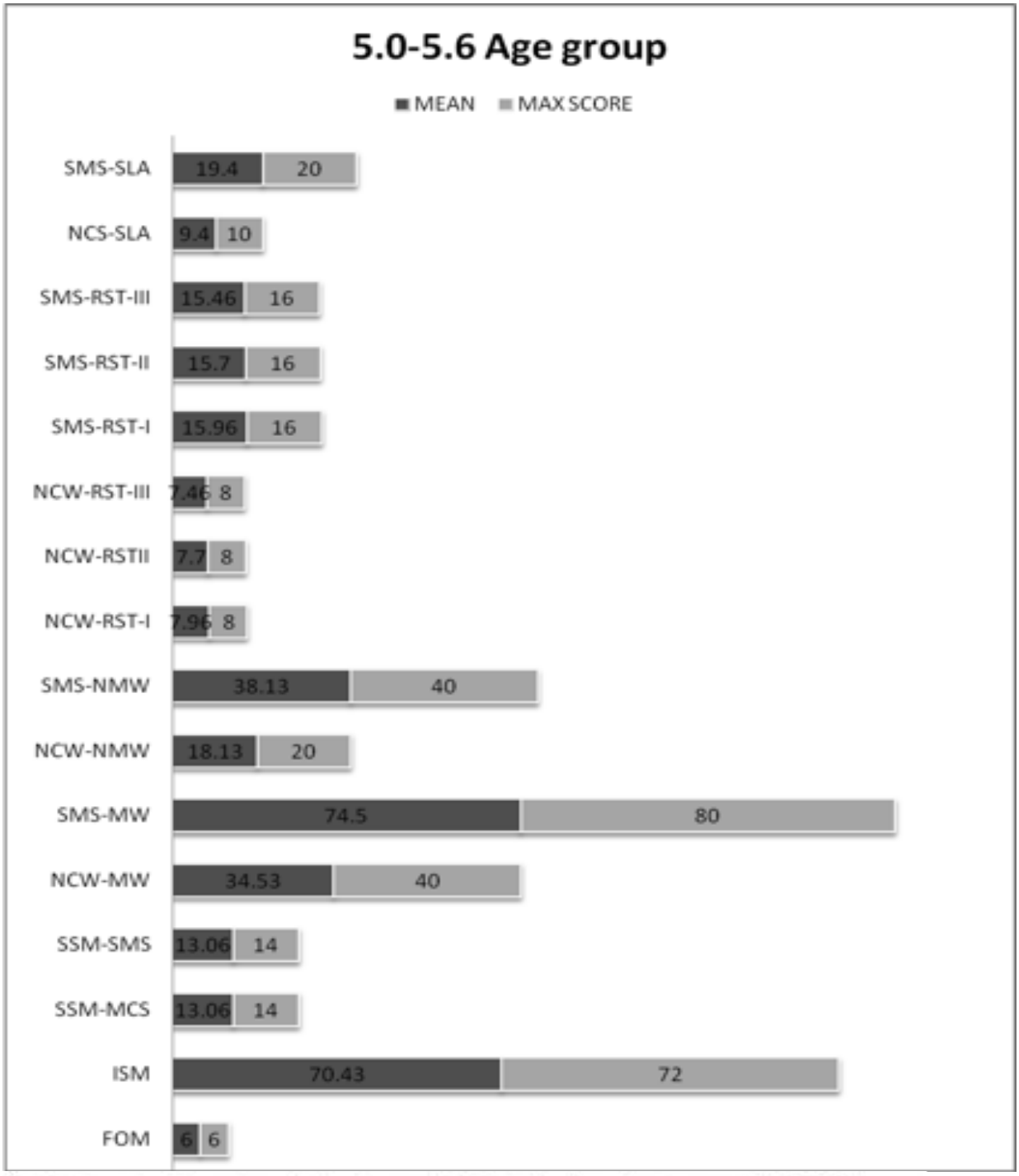
PERFORMANCE GRAPH FOR 4.6-5.0 YEARS



* **FOM**- function of the oral mechanism for speech, **ISM**- Isolated speech movements, **SSM-MSC**- sequential speech movements; motor control score, **SSM- SMS**- sequential speech movements- sequence maintenance score, **NCW-NW**- number of correct words- meaningful words, **SMS-MW**- sequential maintenance score- meaningful words, **NCW-NMW**- number of correct words- non meaningful words, SMS-NMW- sequential maintenance score- non meaningful words, **NCW-RST I**- number of correct words- relational words speech timing I, **NCW-RST-II**- number of correct words- relational words speech timing II, **NCW-RST III**- number of correct words- relational words speech timing III, **SMS-RST**- sequence maintenance score- relational words speech timing, **NCS-SLA**- number of correct sentence-sentence level assessment, **SMS-SLA**- sequence maintenance score- sentence level assessment.

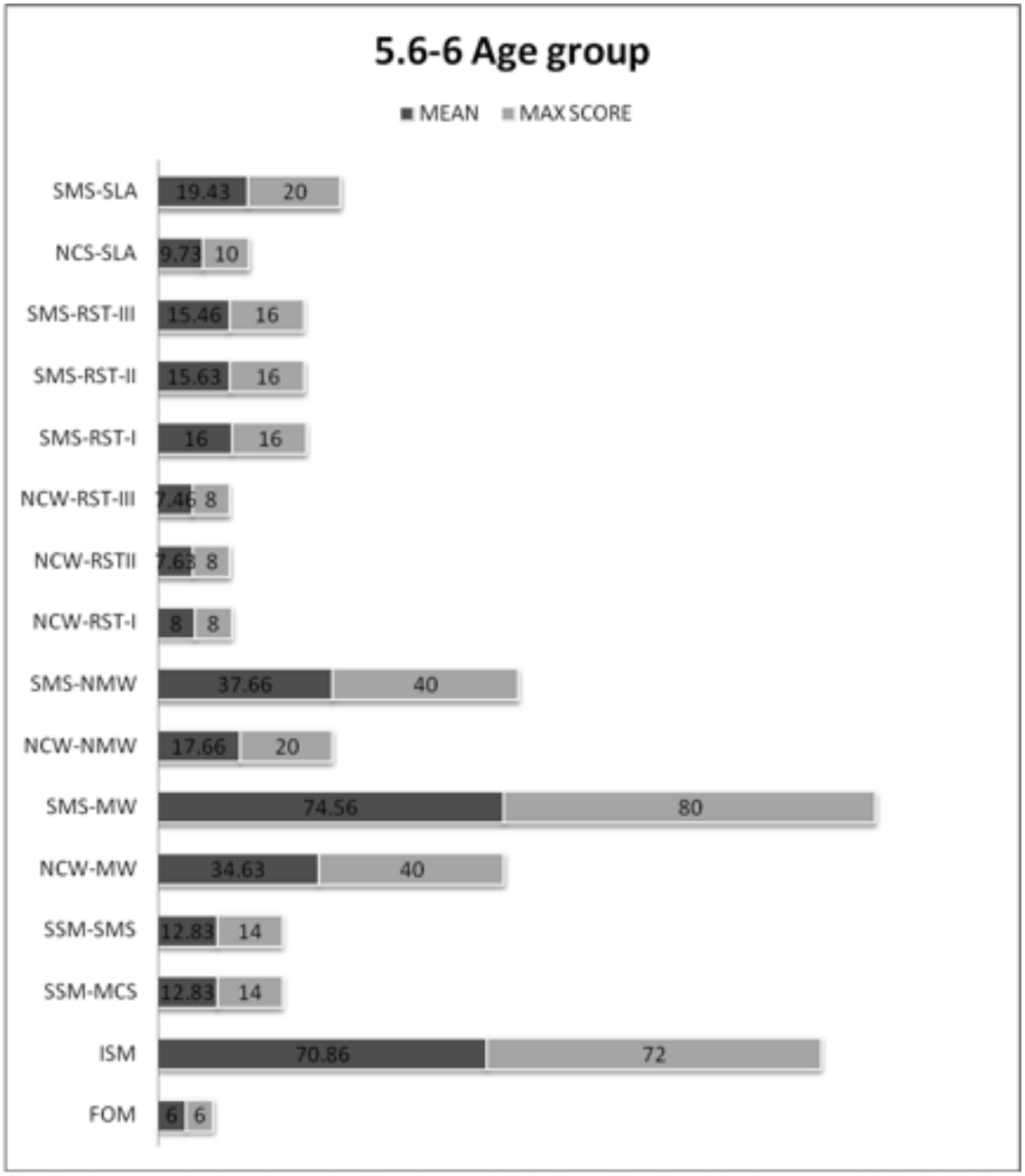
\

PERFORMANCE GRAPH FOR 5.0-5.6 YEARS



* **FOM**- function of the oral mechanism for speech, **ISM**- Isolated speech movements, **SSM-MSC**- sequential speech movements; motor control score, **SSM- SMS**- sequential speech movements- sequence maintenance score, **NCW-NW**- number of correct words- meaningful words, **SMS-MW**- sequential maintenance score- meaningful words, **NCW-NMW**- number of correct words- non meaningful words, SMS-NMW- sequential maintenance score- non meaningful words, **NCW-RST I**- number of correct words- relational words speech timing I, **NCW-RST-II**- number of correct words- relational words speech timing II, **NCW-RST III**- number of correct words- relational words speech timing III, **SMS-RST**- sequence maintenance score- relational words speech timing, **NCS-SLA**- number of correct sentence- sentence level assessment, **SMS-SLA**- sequence maintenance score- sentence level assessment.

PERFORMANCE GRAPH FOR 5.6-6.0 YEARS



* **FOM**- function of the oral mechanism for speech, **ISM**- Isolated speech movements, **SSM-MSC**- sequential speech movements; motor control score, **SSM- SMS**- sequential speech movements- sequence maintenance score, **NCW-NW**- number of correct words- meaningful words, **SMS-MW**- sequential maintenance score- meaningful words, **NCW-NMW**- number of correct words- non meaningful words, SMS-NMW- sequential maintenance score- non meaningful words, **NCW-RST I**- number of correct words- relational words speech timing I, **NCW-RST-II**- number of correct words- relational words speech timing II, **NCW-RST III**- number of correct words- relational words speech timing III, **SMS-RST**- sequence maintenance score- relational words speech timing, **NCS-SLA**- number of correct sentence- sentence level assessment, **SMS-SLA**- sequence maintenance score- sentence level assessment.