ASSESSMENT OF ORAL MOTOR, ORAL PRAXIS AND VERBAL PRAXIS SKILLS IN PERSONS WITH DOWN SYNDROME

Thesis submitted to the University of Mysore for the degree of

DOCTOR OF PHILOSOPHY (Ph.D.)
IN
SPEECH AND HEARING

By

VANI RUPELA

Guide

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All India Institute of Speech and Hearing
Manasagangotri, Mysore - 6, India
January, 2008

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Certificate

This is to certify that the thesis entitled ASSESSMENT OF ORAL MOTOR, ORAL PRAXIS AND VERBAL PRAXIS SKILLS IN PERSONS WITH DOWN SYNDROME submitted by Ms. Vani Rupela for the degree of Doctor of Philosophy to the University of Mysore, Mysore was carried out at All India Institute of Speech and Hearing, Mysore.

Place: Mysore

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Certificate

This is to certify that the thesis entitled ASSESSMENT OF ORAL MOTOR, ORAL PRAXIS AND VERBAL PRAXIS SKILLS IN PERSONS WITH DOWN SYNDROME submitted by **Ms. Vani Rupela** for the degree of Ph.D. in Speech and Hearing, in the University of Mysore, Mysore, is the result of the work done by her at All India Institute of Speech and Hearing, Mysore, under my guidance. I further declare that the results of this work have not been previously submitted for any degree.

Place: Mysore

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Declaration

I declare that the thesis entitled ASSESSMENT OF ORAL MOTOR, ORAL PRAXIS AND VERBAL PRAXIS SKILLS IN PERSONS WITH DOWN SYNDROME which is submitted herewith for the award of the degree of **Doctor of Philosophy (Speech and Hearing)** at the University of Mysore, Mysore, is the result of work carried out by me at the All India Institute of Speech and Hearing, Mysore, under the guidance of Prof. R. Manjula, Ph.D, Professor in Department of Speech Pathology, A.LI.S.H, Mysore.

I further declare that the results of this work have not been previously submitted for any degree.

Place: Mysore

Date: 30/1/08

Vani Rupela

Candidate

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

John Langdon Down, a 19th century English physician first described a group of individuals with the syndrome that was named after him as 'Down syndrome'. The syndrome results most commonly from a chromosomal abnormality called trisomy 21, where an extra third copy of the 21st chromosome is present. Down syndrome is a relatively common and easily identifiable syndrome because of its physical and mental characteristics.

Speech and language deficits are reported to be some of the prominent features in Down syndrome. Children with Down syndrome have physiological characteristics that can affect communication and a great deal of research has been carried out to study the communicative characteristics of this population (Paul, 2001). A higher incidence of speech problems is reported in children and adults with Down syndrome than any other group of people with learning difficulties (Schlanger & Gottsleben, 1957; Blanchard, 1964). Persistent deficits in speech intelligibility are also reported in this group of individuals (Chapman, 1995).

Most of the research on speech impairments in Down syndrome (DS) is focused on issues related to phonology. These phonological problems have been ascribed to different factors including hearing loss, deficits in motor co-ordination, differences in anatomy and physiology of the oral mechanism, language environment, perceiving and encoding speech, and presence of chronic upper respiratory infections (Stoel-Gammon, 1997,2001; Dodd & Thompson, 2001). Over the years, these factors including deficits in motor co-ordination and specifically praxis errors have been studied by a number of investigators (Elliott, Weeks, & Gray, 1990; Hamilton, 1993; Kumin & Adams, 2000).

Individuals with Down syndrome are reported to have skeletal and muscular systems that differ from those individuals without Down syndrome (Miller & Leddy, 1998; Leddy, 1999). Hypotonia, weakness in oral structures, limited movements of oral structures and structural deficits of the oral cavity (a high palatal vault) and tongue size in relation to oral cavity are reported to affect speech production in persons with Down syndrome. Oral hyposensitivity and hypersensitivity have also been reported in young children with Down syndrome (Frazier & Friedman, 1996).

Some investigators have also evaluated the presence of motor planning and co-ordination or praxis deficits i.e. presence of Childhood apraxia of speech in persons with Down syndrome. Childhood apraxia of speech (CAS) is defined as a "neurological speech sound disorder in children in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g., abnormal reflexes, abnormal tone) (ASHA, 2007). CAS may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of known or unknown origin, or as an idiopathic neurogenic speech sound disorder. The core impairment in planning and / or programming spatiotemporal parameters of movement sequences results in errors in speech sound production and prosody" (ASHA, 2007). ASHA (2007) also states that CAS occurs as a primary or secondary sign in children with complex neurobehavioral disorders (e.g. genetic, metabolic).

According to motor learning principles, speech production skills develop through learning and experience (Caruso & Strand, 1999). Hence it is important to address oral and verbal praxis deficits in persons with Down syndrome. During the initial stages of development, the child needs to use very controlled processing in order to manage this complex motor skill of speech production. As children develop and use speech, some of these movements become well practiced or habituated and more practiced movement gestures require less conscious processing (Caruso & Strand, 1999). In order to acquire such practiced movement gestures in speech, it is also important to have adequate auditory, kinesthetic and proprioceptive input. It is necessary to process all the incoming sensory input in order to develop the motor plans needed for motor speech acts (Kumin & Adams, 2000). Neuroanatomical, neurophysiologic and neuromuscular changes over the course of development influence early word production. Speech development takes place due to a combination of cognitive and linguistic factors; and neuromaturation (motor and sensory) of the vocal apparatus. If the natural development of these factors is impaired or delayed, speech acquisition can be affected.

Persons with Down syndrome have distinct features in their nervous systems that serve to delay the neuromaturational processes required for speech development. Such deficiencies in neuroanatomical structures can lead to developmental delays in both motor (Lauteslager, Vermeer, & Helders, 1998) and speech (Lenneberg, 1967; Miller &

Leddy, 1998; Chapman & Hesketh, 2000) milestones in persons with Down syndrome. Oral motor problems that occur due to hypotonia, small oral cavity and macroglossia may also add to these delays. Because these delays occur during the early developmental period, the effect may remain until later due to which the child is likely to have motor learning problems that can lead to praxis difficulties.

Few investigations of CAS as a secondary disorder in persons with Down syndrome have been carried out. Ferry, Hall and Hicks (1975) reported developmental verbal dyspraxia (referred to as CAS in the study) in two subjects with Down syndrome. Elliott et al., (1990) reported oral praxis deficits in adults with Down syndrome. Hamilton (1993) investigated electropalatographic (EPG) patterns in adults with Down syndrome and observed specific EPG patterns similar to those seen in children with apraxia such as presence of long closure durations, slow approach and release phases for closures, abnormally long transitions between different elements of consonantal clusters, difficulty in repeating CV (consonant-vowel) syllables, erratic and arrhythmic production of CV sequences, asymmetry and variability in articulation of fricatives.

Kumin and Adams (2000) evaluated seven children with Down syndrome and listed the overlapping characteristics of Childhood Apraxia of Speech (CAS) observed in children with Down syndrome such as voicing errors, inconsistent errors, increased difficulty in volitional oral tasks than automatic ones, superior receptive language when compared to expressive language, and better speech intelligibility when producing familiar words or phrases. Other characteristics such as poor syntax or morphology, and reduced speech intelligibility with increased length of utterance; especially in unknown contexts were also reported. Kumin and Adams (2000) also observed speech sound errors such as increased occurrence of sound omissions, perseverative and anticipatory articulatory errors.

Investigation of oral motor, oral praxis and verbal praxis issues in persons with Down syndrome is very important and has a bearing on the speech assessment and treatment programs. Over the years, issues relating to therapy for improvement of speech production in persons with Down syndrome have focused on the oral motor (dysarthric) point of view and have generally failed to address the motor planning and programming difficulties (Kumin & Adams, 2000). Presence of praxis errors may help in a more appropriate estimation of severity of the problem, which can further dictate the decision with respect to the type of assessment and intervention that is required. Such an approach will help a speech pathologist to aim at not only improving linguistic skills, but also, target the speech motor system. There is not enough evidence in the literature investigating for the presence of both oral motor and praxis deficits in persons with Down syndrome. In the Indian population, such investigations are not reported which may be due to lack of appropriate assessment tools. Hence, the present study aimed to investigate oral motor, oral praxis and verbal praxis skills in Kannada speaking persons with Down syndrome by developing a protocol to test these three skills. Kannada is a Dravidian language spoken in the southern Indian state of Karnataka.

Aims of the study

1) To develop a protocol for the assessment of oral motor, oral praxis and verbal praxis skills in Kannada language.
2) To carry out a pilot study and administer the protocol on a fraction of the participant groups to check for the appropriateness of scoring and instructions.
3) To compare four groups of subjects for oral motor, oral praxis and verbal praxis skills- (a) Experimental group: persons with Down syndrome (b) Control group I: mental age matched persons with mental retardation (without DS) (c) Control group II: chronological age matched typically developing children (d) Control group III: mental age matched typically developing children.

Method

Participants

The age range of the participants with Down syndrome was 11;6 to 14;6 years keeping in mind that speech motor control is reported to be complete and mature by around 11 to 12 years of age in normal children (Kent, 1976; Kent & Forner, 1980). While information about the development of speech motor control in children with Down syndrome is not known, they reportedly show a linear increase in mean length of utterance (MLU) until early adolescence (Rondal, 1996). In order to be able to obtain a considerable amount of verbal output from the participants, persons in the age group of

11;6 to 14;6 years were selected. The experimental group consisted of persons with Down syndrome who were compared with three control groups that included (a) chronological and mental age matched persons with mental retardation, (b) mental age matched typically developing children, and (d) chronological age matched typically developing children. Persons with mental retardation as control group I were included in order to study the influence of mental retardation on speech issues that was a constant factor with that of the experimental group i.e. persons with Down syndrome. Typically developing children from two age groups were included. Control group II included chronological age matched typically developing children between 11;6 and 14;6 years and control group III had mental age matched typically developing children in the age range of 4;1 to 6; 10 years.

Protocol

An assessment protocol was compiled and developed by drawing the items from various sources in the literature. The items were specifically designed to meet the needs of Kannada speaking individuals in the age range of 4 to 7 years, i.e. the mental age of individuals targeted in the experimental and control group I. Verbal stimuli in Kannada that were used in the verbal praxis protocol were developed. The selected items were subjected to a familiarity rating before administering the test. A linguist was also consulted in order to determine the appropriateness of vernacular form of the stimuli selected. A pilot study was done before finalizing the protocol under the three sections of oral motor, oral praxis and verbal praxis skills. In the pilot study, parameters such as effectiveness of the protocol, appropriateness of instructions and scoring were determined. Before administering the assessment protocol, an informed consent was obtained from parents or caregivers. Based on the results obtained from the pilot study, the assessment protocol was modified. The final form included three sections- oral motor, oral praxis and verbal praxis assessment protocols. However, after the pilot study, two sections viz. assessment of posture and oral sensory assessment protocols were not included in the final analysis because they did not reveal any significant differences between the experimental and control groups. The protocol including these two sections is presented in Appendix 1.

Items / measures in protocol; their analysis and/ or scoring

There were three main sections in the assessment protocol and they are, assessment of oral motor, oral praxis and verbal praxis skills.

- The first section included an oral motor protocol that consisted of assessment of oral structures at rest, and function of oral structures during speech. Two and three-point rating scales were used to assess the items in the oral motor protocol.
- The oral praxis protocol incorporated assessment of isolated, and sequential oral movements. In this section, participants were instructed to imitate the movements as demonstrated by the investigator. Isolated oral movements were evaluated in terms of accuracy, rate of movements and numbers of repetitions required. On the other hand, sequential oral movements were rated for correctness in terms of accuracy of movements and sequences. A five-point rating scale was used to

assess isolated oral movements and a three-point rating scale was used to rate the sequential oral movements.

The verbal praxis protocol was designed to assess verbal tasks in a hierarchical manner of complexity including assessment of isolated verbal movements, sequential verbal movements, diadochokinetic (DDK) tasks, assessment of words, sentences and spontaneous speech. Participants were instructed to imitate the investigator's verbal movements for all items of the verbal praxis assessment protocol except for the assessment of spontaneous speech.

> A four-point rating scale was used to assess isolated verbal movements where scores were given in terms of accuracy of movements and numbers of repetitions required.

> Sequential verbal movements were evaluated in terms of accuracy of movements (motor control score) and sequences (sequential motor score) on two-point rating scales.

> Assessment of diadochokinetic (DDK) tasks was done in terms of rate (iterations per second) for both Sequential Motion Rate (SMR) and Alternate Motion Rate (AMR) tasks. Apart from rate, DDK assessment also included analysis of numbers of attempts required to produce responses, accuracy and consistency of DDK tasks.

> Words were analyzed for phonological processes and the processes were further divided into space, timing and whole-word errors. Analyses at word level also included a sequence maintenance score that was calculated per word on a three point rating scale.

> Sentences were scored using a sequence maintenance score based on a three-point rating scale. Percentages of consonants and vowels correct scores (PCC and PVC) were also calculated at sentence level.

> Spontaneous speech was analyzed using PCC, and PVC scores; numbers of disfluencies, and groping. Phonotactic assessment of spontaneous speech was also carried out.

Administration, set-up and recording

All children were tested individually; in fairly quiet and familiar surroundings and the audio-video recordings were done using a Panasonic digital camcorder NV GS-15. The video recordings were supplemented with audio recordings that were done using a digital voice recorder VY-H350 with an external microphone placed approximately 10 cm from the mouth of the participant. The video camera was placed on a tripod stand in front of the child and the investigator was seated at a 45° azimuth from the child away from the view of the camera. Video recording was started whilst administration of the test battery where positive feedback and appropriate cues were given in order to elicit the speech. These recordings were viewed on a 17 inches wide computer monitor and analyzed based on auditory and visual cues.

Transcription and reliability measures

Each child's sample was analyzed separately and scores were given in the scoring sheet. Transcription was carried out using broad IPA transcription method along with a few diacritic markers. Reliability measures were done in order to establish the reliability of the protocol, rating scores and that of IPA transcription. Reliability measures included test-retest reliability, inter- and intra-judge reliability of rating and transcription. Two different judges were involved who were matched in age, gender, education, and work experience with the principal investigator. Reliability quotients were established on statistical analyses along with segment to segment inter and intra-transcription reliability.

Statistical analysis

In order to compare the performance across the three groups viz. persons with Down syndrome, persons with mental retardation (without DS) and typically developing children, statistical analyses were carried out. The different statistical tests used were one-way ANOVA, Duncan's post-hoc test, Friedman test, Wilcoxon signed rank test and uncorrelated equality of proportions.

Results

Results are presented in three sections of oral motor, oral praxis and verbal praxis skills. Salient findings are presented as follows:

- Persons with Down syndrome exhibited greater problems in oral motor skills than the other three groups. No differences were found between the three control groups of persons with mental retardation (without DS) and typically developing children (chronological and mental age matched). Oral motor problems in persons with Down syndrome were mostly seen in terms of hypotonia as suggested by the placement of oral structures such as lips, tongue and jaw at rest. Function of oral structures during speech was also affected in terms of maintenance of oral-nasal distinction, air build up for stops, and fricatives.

- Persons with Down syndrome also exhibited deficits in oral praxis skills in terms of isolated and sequential oral movements. Isolated oral movements were affected in persons with mental retardation (without DS) as well, but not in as much degree as in persons with Down syndrome. Sequential oral movements assessment reflected significant deficits in sequencing of oral movements in persons with Down syndrome that are important indicators of CAS.
- Assessment of verbal praxis skills revealed deficits in all the items assessed.
    - Significantly greater deficits when compared to the control groups were noticed for isolated verbal movements assessment in terms of accuracy and numbers of cues required.
    - Sequential verbal movements assessment revealed significantly greater deficits in accuracy and sequencing of speech sounds by persons with Down syndrome when compared to the control groups.
    - Assessment of DDK tasks showed significant differences between the group with Down syndrome and the control groups in terms of rate (iterations per second) for the SMR task and not for the AMR tasks. Persons with Down syndrome required greater numbers of attempts, exhibited more errors of articulation such as place, voicing, deletion, and

perseveration errors. They also had greater inconsistencies from one repetition to another (in SMR tasks) than the control groups.

> Phonological process assessment at word level showed that persons with Down syndrome used more numbers of different phonological processes when compared to the control groups. Errors suggestive of praxis deficits such as presence of high degree of omissions, atypical errors, voicing and vowel errors were also present in persons with Down syndrome. Sequence maintenance in terms of the number and sequence of syllables in words was also significantly more affected in persons with Down syndrome.

> Sentence level and spontaneous speech assessment using PCC, and PVC scores also revealed greater verbal praxis deficits in the experimental group (persons with Down syndrome).

> Phonotactic assessment was also done for spontaneous speech samples that revealed use of simpler phonotactic shapes such as CV syllables, medial geminated clusters and disyllabic words when compared to the control groups. Persons with mental retardation (without DS) and typically developing children showed significantly greater occurrences of complex shapes such as CVC syllables, initial clusters, medial non-geminated clusters and multisyllabic words.

In all three domains of oral motor, oral praxis and verbal praxis skills, persons with Down syndrome exhibited more deficits than the control groups. A perceptual protocol was used to identify these deficits and analysis revealed that some persons with

Down syndrome did exhibit praxis deficits i.e. Childhood Apraxia of Speech (CAS). These deficits were present along with oral motor deficits such as hypotonia. However, most of the oral and verbal praxis deficits could be differentiated from oral motor skill deficits. For example, sequencing errors in both oral and verbal domains were due to praxis deficits and could not be caused due to sluggish movements of oral structures due to hypotonia. While persons with Down syndrome exhibited poorer performance when compared to the control groups, not all of them exhibited similar type or degree of deficits across the tasks.

Limitations

The present study explored oral motor, oral praxis and verbal praxis skills in persons with Down syndrome using a perceptual method. The assessment was carried out in Kannada, a language that has not been extensively studied. The results obtained through perceptual method were not substantiated with acoustic data.

Implications

Implications of this study are varied in terms of both assessment and therapy options for persons with Down syndrome. They are:

- To incorporate a detailed oral and verbal praxis assessment in persons with Down syndrome other than just oral motor and language skills assessment. It is important to assess for the presence of praxis deficits in Down syndrome because if oral and / or verbal praxis deficits exist, then the line of therapy would have to be geared towards those deficits.

- To target the oral and verbal praxis deficits in speech therapy if found to be affected. Therapy for oral praxis deficits would incorporate intensive training on a hierarchy of tasks from simple to complex ones. Intervention strategies for verbal praxis deficits would include phonological therapy using a hierarchy of simple to complex tasks customized for the needs of the child, targeting syllable level errors instead of phonemic ones, and maximizing the use of auditory, visual and tactile cues.
- Another important implication of the presence of praxis deficits would be to focus on the cause of CAS in children. There is a dire need to find out the genetic markers of CAS. Enough evidence to the presence of CAS in Down syndrome warrants future research to be directed towards the 21st chromosome.

REVIEW OF LITERATURE

Language and communication deficits are the most common consequences of a variety of disorders that affect mental development. There are as many causes of language disorders as there are conditions with which language disorders are associated (Paul, 2001). Down syndrome is only one of those. It is one of the most common chromosomal abnormalities with an estimated incidence of one in every 700 live births (Miller & Leddy, 1998). It is a genetic condition that gives rise to a varied and extensive range of language and speech disorders (Farmer & Brayton, 1979). Persons with Down syndrome present characteristics such as hypotonia, mild to moderate mental retardation, facial dysmorphy, reduced anterior-posterior dimension of the head (brachycephaly), hyperflexibility of joints, ear anomalies, oral motor difficulties and deficits in speech, language and hearing (Paul, 2001).

Down syndrome occurs because of any one of the three chromosomal errors: (a) Trisomy 21, (b) Mosaicism and (c) Translocation. The most common is trisomy 21, which results from a failure in disjunction of the 21^{st} chromosome during meiosis of embryonic development. In other words, for some unknown reason, the chromosomes fail to divide properly i.e. from 46 to 23 chromosomes. Errors in disjunction can occur in mitosis, rather than meiosis, causing some cells to have the trisomy and some cells to be normal. This occurrence is called mosaicism, which usually results in less severe symptoms. Down syndrome can also result when part of a 21^{st} chromosome breaks, often reattaching to another chromosome, usually the 13^{th}, 14^{th} or 15^{th}. This phenomenon is called translocation, and this type of transmission is often genetically inherited, whereas trisomy and mosaicism are not (Crane, 2002).

Communication deficits in persons with Down syndrome are extensively documented in terms of language development starting from prelinguistic development to the development of morphosyntactic structures. Few differences have been documented in the pattern of prelinguistic development of infants with Down syndrome and typically developing children. Most of the investigators (Dodd, 1972; Smith & Oiler, 1981; Smith & Stoel-Gammon, 1983; Oiler & Siebert, 1988; Steffens, Oiler, Lynch, & Urbano, 1992) reported that prelinguistic development in infants with Down syndrome was similar to that of typically developing children in terms of quantity of vocalization produced, and the developmental pattern. This prompted Stoel-Gammon (1997, 2001) to conclude that Down syndrome appears to have relatively little effect on prelinguistic vocal development. Chapman and Hesketh (2000) added that although there was no difference in vocalization types, children with Down syndrome were slower in transition from babbling to speech and had poor speech intelligibility.

Acquisition of meaningful speech is reported to be delayed in children with Down syndrome and many children used conventional words after three years of age (Rondal, 1996; Miller & Leddy, 1998). Extreme variability has also been reported in the age of acquisition of first words. Stray-Gunderson (1986) reported that while some children produced words at 9 months, similar to that of typically developing children, others showed a delay of as much as 7 years. In summary, the onset of meaningful speech is reportedly delayed in infants with Down syndrome and after the appearance of words; growth of productive vocabulary is exceedingly slow. Although semantic development is also retarded in individuals with Down syndrome (Rondal, 1996), it is generally thought to be better than other domains of language (Miller & Leddy, 1998; Layton, 2001). Miller (1988) called this disproportionate language development in children with Down syndrome as an 'asynchrony in the acquisition of language' manifested by the marked difficulty in productive language skills when compared to comprehension abilities.

The review of literature will focus on speech production deficits in persons with Down syndrome, including those of phonology, fluency and speech intelligibility. However, more emphasis will be placed on phonological deficits because (a) majority of the research on speech impairments is focussed on issues related to phonology; and (b) phonological issues are more relevant to this study. The review is organized as follows:

1.0 . Speech production deficits in persons with Down syndrome

  1.1. Phonological deficits

  1.2. Fluency deficits

2.0 , Factors affecting speech production in persons with Down syndrome

3.0 . Oral motor deficits in persons with Down syndrome

  3.1. Oral motor, oral sensory and postural control deficits

  3.2. Factors related to oral motor deficits that affect speech production

4.0 . Oral and verbal praxis deficits in persons with Down syndrome

  4.1. Definitions and historical background

1.0. Speech production deficits in Down syndrome

1.1 Phonological deficits

When speech, language and communication are compared, speech is by far reported to be the most difficult for children with Down syndrome to acquire (Kumin, 2002). Children and adults with Down syndrome present a greater incidence of speech problems than any other group of people with severe learning difficulties (Schlanger & Gottsleben, 1957; Blanchard, 1964; Rondal, Lambert, & Sohier, 1981). Articulation problems are reported to be particularly severe in those with Down syndrome (Schlanger & Gottsleben, 1957; Blanchard, 1964; Dodd, 1976; Stoel-Gammon, 1981). The speech in individuals with Down syndrome is often reported to be unintelligible, but language skills (verbal comprehension) are reportedly better than speech, unlike other children with intellectual disability (Miller, 1987; Rondal & Edwards, 1997; Dodd & Thompson, 2001; Layton, 2001). Few investigators have also reported that speech of some individuals with Down syndrome tends to remain unintelligible throughout their lives (Pueschel & Hopman, 1993; Kumin, 1994).

1.1.1 Studies supporting the hypothesis of 'delay' in phonological development of individuals with Down syndrome

Earlier studies that reported articulatory deficits in persons with Down syndrome were mostly descriptive and often cited phonemic errors or errors in phoneme acquisition. Most of these studies supported the notion that phonological development in children with Down syndrome was delayed but it followed the same pattern in general as that of typically developing children. Some investigators (Stoel-Gammon, 1980; Rondal, 1993; Van Borsel, 1996) argued that speech development in individuals with Down syndrome was merely delayed, while others (Dodd, 1976; Stoel-Gammon, 1981; Willcox, 1988; Rondal & Edwards, 1997) claimed that the delay in speech development was attributable not only to their cognitive limitations, but also to factors that were specific to Down syndrome.

Various studies supported the notion that phonological development is 'delayed' in individuals with Down syndrome. Schlanger and Gottsleben (1957) observed that ninety five percent of English-speaking subjects with Down syndrome presented articulatory deviations. The shortcoming of the study however, was that the error types and intelligibility measures were not included (Stoel-Gammon, 1980). Zisk and Bialer (1976) delineated the order of difficulty in phoneme articulation, with /s/ and other sibilant sounds being most affected, followed by affricates /ʧ/ and /ʤ/, fricatives /f/, /v/, /θ/, and /ð/ and plosives, /k/ and /g/. Defects in /r/ and /l/ were also reported especially in blends. These studies provided information about individual phonemic units, but analysis of phonological processes provides information on more than a single element or an adjacent pair of segments and this was not addressed in this study.

Dodd (1976) studied large numbers of children with Down syndrome and compared their phonological errors with two other groups of children matched for their mental age. The average age of children in the groups with disorders was 10;7 years, matched according to mental age with typically developing children in the age range of 2;7 to 4;7 years. The two comparison groups were:

a) Non-Down syndrome children with mental retardation, and

b) Typically developing children.

They were evaluated on two elicited tasks:

a) Picture naming, and

b) Lexical imitation.

Children with Down syndrome produced more errors and greater numbers of error types than the other two groups. Three types of systematic phonological errors were observed in all three groups of children: cluster reduction, consonant harmony and simplification of the phonological system (e.g. deletion of unstressed syllables; initial /h/; nonsonorant consonants; initial, syllabic, final and intervocalic /I/; /r/; nasals; and final /s,z/). Amongst persons with Down syndrome, a large number of errors such as difficulties in production of a sound, interpolation of consonant between two vowels, omission of syllables and inconsistent substitutions and omissions were also observed.

Dodd (1976) also found that the set of 23 phonological rules that could account for all the errors in the speech of typically developing children did not suffice to account for those of children with Down syndrome. Children with Down syndrome were observed to exhibit more inconsistent errors on subjective evaluation when compared to the other two groups. Since the phonological analyses were done solely using elicited single word productions but not continuous speech samples, the results could not be considered as a reliable database for phonological rule analysis (Shriberg & Kwiatkowski, 1979).

Few other investigators attempted a more comprehensive evaluation including phonetic/phonemic and phonological process analyses to study the phonology in persons with Down syndrome. Bleile and Schwarz (1984) studied the phonological patterns of three children with Down syndrome aged 3;4, 3;6 and 4;6 years in terms of phonologic oppositions, phone acquisition and phonologic processes in a free play situation.

a) To study phonologic oppositions, multiple renditions of individual words were analyzed for each child. This method indicated the phonemes used to substitute with other phonemes and hence revealed meanings that the children wanted to express using their limited phonologic systems. They found that stop, nasal and glide consonants were produced accurately while fricatives, affricates, and liquids were often erred. This approach however, did not provide information regarding addition, omission and distortion errors.

b) Using phone acquisition, details regarding the 'phones' that the children were able to produce correctly were obtained. It was found that while each child differed from the others, none of them were observed to have any unusual 'phones' in their repertoire.

c) Using phonological process analysis, stopping, fronting, prevocalic voicing, unstressed syllable deletion, velar and labial assimilation, cluster reduction and gliding were identified as some of the common phonological processes used by the three children with Down syndrome.

While this study provided comprehensive information regarding phonemic and phonological repertoires of children with Down syndrome, the sample was restricted to three children, so these findings were difficult to generalize.

Very few studies have investigated the phonological problems in a large number of children with Down syndrome. But studies in a small group of children are more successful in presenting comprehensive data for each subject. Stoel-Gammon (1980) analyzed spontaneous speech samples of four children aged 3;10 years to 6;3 years with Down syndrome having mild mental retardation. Analyses were done in three ways:

a) The phonetic inventory for each child was obtained

b) Error types (substitutions, assimilations, and deletions) were analyzed

c) Phonological process analysis was carried out

It was concluded that children with Down syndrome could produce all phonemes in English although not in all positions of the word. The findings of this study were consistent with previous ones, in terms of phoneme acquisition, and phonological processes with a few exceptions. For example, unlike findings of Zisk and Bialer (1976) velars were not prone to error and liquid deviations were evidenced often. Phonological processes other than those reported by Dodd (1976) were (a) a tendency for weakening of consonants in final position, (b) voicing of intervocalic consonants, and (c) deletion of alveolar flaps. Based on the findings of this study Stoel-Gammon (1980) concluded that speech of children with Down syndrome was delayed because their articulation was related to adult forms in regular and predictable ways.

The notion of 'delayed' phonological development was also supported in a longitudinal study of stop consonant production by Smith and Stoel-Gammon (1983) who concluded that both children with Down syndrome aged 3 to 6 years and typically developing children produced similar patterns of errors. For example, stop targets were produced correctly in initial position more often than in final position by both groups and; majority of the incorrect productions in both groups were caused due to voicing errors. In terms of phonological process analyses they found a trend towards an increased difference between the two groups over time suggesting that children with Down syndrome tended to fall increasingly farther behind with age in terms of phonology.

Stoel-Gammon (1997, 2001) summarized the following phonological processes used by children with Down syndrome based on various sources from the literature (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon, 1983): (a) Consonant clusters produced as singleton consonants (the process of Cluster Reduction); (b) Word final consonants deleted (Final Consonant Deletion); (c) target fricatives produced as stops (Stopping); (d) aspirated voiceless stops in initial position deaspirated (Prevocalic voicing); (e) word initial liquids produced as glides (Gliding); (f) word final liquids produced as vowels (Vocalization); (g) word final obstruents devoiced (Final Consonant Devoicing).

1.1.2 Articulatory and phonological deficits in older children and adults

The articulatory and phonological problems found in children are often reported to persist throughout adulthood. Relatively few investigations have been carried out on older children and adults with Down syndrome. Van Borsel (1988) analyzed the speech of five Dutch-speaking girls with Down syndrome in the age range of 16;5 to 19;9 years for phonetic, substitution and phonological process errors. Phonetic analysis revealed that the subjects could produce most of the speech sounds in all positions of the word except fricatives, glides and a few plosives. Increased variability among subjects was observed with respect to distribution and frequency of substitutions. However, a few general tendencies were seen indicating that voiced plosives and fricatives were more frequently substituted than their voiceless cognates. Three of the four subjects exhibited higher percentages of substitution for fricatives and liquids; and lowest for glides. The analysis did not include distortions and a high percentage of omissions were observed that were considered as substitution by a 'zero element'. Phonological process analysis revealed that four processes were used commonly by all the children. They were, cluster reduction, deletion of final consonants, fronting of palatals and devoicing of voiced plosives and fricatives. Three other processes that were used frequently but not by all four subjects were liquid deviation, backing of /t/ and /d/, and deletion of unstressed syllables. Other minor processes such as assimilation, post-vocalic devoicing, metathesis, and reduplication were also observed. Although no patterns were apparent in the speech errors, Van Borsel (1988) concluded that to a great extent, these errors were regular, supporting the notion of 'delay' in phonological development in persons with Down syndrome. This was one of the few studies that investigated phonological patterns of children above 15 years of age. The method of elicitation used was naming of line drawings and continuous speech that is considered the most reliable stimulus base for phonological rule analysis (Shriberg & Kwiatkowski, 1979). The study by Van Borsel (1988) however had some methodological limitations such as small sample size and lack of discernible data to compare with mental age matched individuals with mental retardation or typically developing children, thus rendering generalization difficult.

In a comprehensive study of older persons with Down syndrome, Sommers, Patterson and Wildgen (1988) gave detailed information on the use of phonological processes and distinctive features. Two groups of individuals with Down syndrome aged 13-17 years and 17-22 years were included to evaluate developmental trends with respect to these errors. Speech samples included connected discourse, spontaneous picture naming, and imitation. The study revealed that except for a few characteristics, older persons shared the same characteristics as the younger ones. A combination of delayed and deviant phonology was observed in both the groups of participants. In defense of the 'delayed' hypothesis, the investigators reported:

a) That the most common processes used by the subjects in the study were final consonant deletion, cluster reduction, liquid gliding and vocalization;

b) The use of same processes and distinctive features as used by younger typically developing children.

Supporting the 'deviancy' hypothesis on the other hand, investigators observed that:

a) Simplifications involving final consonant deletions that were among the first phonological process to disappear in normally speaking children (Ingram, 1976), were inconsistent with categories specified by Ingram (1981). These inconsistencies were hypothesized to be due to deficits in 'motor preplanning'.

b) A higher percentage of errors were associated with stop consonants in spite of stops being amongst the first consonants to be acquired in typically developing children (Prather, Hedrick, & Kern, 1975).

c) Amongst distinctive features, +vocalic for *Ixl* and *IV* and +nasal features were more difficult than features that affected later developing phonemes.

The study did not compare the results directly with mental age matched typically developing persons. It also compared younger and older persons from different groups and did not follow a longitudinal approach that would have served to comment on phonological development.

Another investigation of persons with Down syndrome of age 15;4 to 28;3 years was conducted by Van Borsel (1996). In this study, phoneme error rates in persons with Down syndrome were compared with those of younger typically developing children between the ages of 2;6 to 3;4 years. It was observed that both groups of children exhibited errors that were:

a) Comparable in terms of consonant error rates
b) Most often on the same sounds
c) Similarly influenced by phonetic context (more errors with syllable-final consonants than with syllable-initial consonants and more with consonants of clusters than with singleton consonants)
d) Similar in types of distortion, addition, and sound sequence alterations made
e) Similar for vowels and diphthongs.

The analyses of phoneme errors were carried out in great detail, incorporating vowel, diphthong, and distortion errors. However, analysis of omissions did not include syllable deletions and the issue of how subjects treated a syllable or word on the whole was not addressed. Also, analysis for different error types was done separately and in a different context. For example, while substitutions were analyzed considering the phonetic context, the same was not carried out for the analysis of additions or distortions.

Shriberg and Widder (1990) analysed continuous speech samples of 20-50 year old persons with mental retardation that included 8 samples from those with Down syndrome and compared the same with those of speech-delayed children. Phonological processes such as cluster reduction, liquid simplification, final consonant deletion, stopping, unstressed syllable deletion, velar fronting, and palatal fronting were analysed. They observed that except for final consonant deletion, adults with mental retardation exhibited significantly lesser numbers of errors than speech delayed children. The findings of this study mostly support delayed phonological development, but the samples of subjects with Down syndrome were not analysed separately and hence it would be difficult to generalize the findings of this study.

Summing up the literature on phonological deficits in older persons with Down syndrome, it can be concluded that similar speech characteristics, speech errors, and reduced intelligibility are reported for adults as they are for younger persons with Down syndrome (Rondal & Comblain, 1996). Shriberg and Widder (1990), and Hamilton (1993), for American English and English-speaking subjects with Down syndrome respectively, and Van Borsel (1988, 1996), for Dutch-speaking adolescents and adults with Down syndrome, report that consonant error rates and typical speech errors found in this group were comparable to those found in children with Down syndrome, specifically in terms of:

a) Increased errors in syllable final positions;

b) More errors on consonant clusters when compared to singleton consonants;

c) The types of errors i.e. substitutions, additions, and omissions.

/. 1.3. Studies supporting deviancy in phonological development of individuals with Down syndrome

While most studies supported the notion that phonological development of persons with Down syndrome is delayed, some have suggested 'deviancy' in phonological development. Dodd (1976) reported that although no significant differences were found in the numbers of errors seen in children with Down syndrome in comparison with mental age matched children with mental retardation (without Down syndrome) and typically developing children, the errors made by the children with Down syndrome were more variable. In addition, a greater number of idiosyncratic phonological processes were observed, and this was cited as an evident sign of difficulty in motor speech programming in children with Down syndrome. The aspect of greater variability in errors was also supported by Stoel-Gammon (1981). Typically developing children showed a small set of substitution types and moved from incorrect to correct phoneme production in a linear fashion. In contrast, children with Down syndrome exhibited a greater range of substitution types and these varied from one word to another (Stoel-Gammon, 1981).

Dodd and Thompson (2001) addressed the issue of inconsistent phoneme production in real words in fifteen children with Down syndrome aged 67 to 190 months and compared the performance with a control group of intellectually normal children with 'inconsistent speech disorder'. Children from both groups were matched for percentages of phonemes pronounced correctly and additionally tested using the 25-word inconsistency test developed by Burt, Holm and Dodd (1999). Results revealed no significant differences between the two groups in terms of the whole-word measures of inconsistency. However intellectually normal children with speech disorders were able to make a greater numbers of changes within words across trials, highlighting the presence of persistent nature of phonological problems in persons with Down syndrome. Since the age ranges in the two groups were quite varied, around 67 to 190 months in persons with DS and from 43 to 65 months in intellectually normal children, the influence of chronological age on the results derived was not ruled out. Also, as acknowledged in the study, the mental ages in terms of non-verbal comprehension between the groups could not be matched and hence a group with inconsistent speech disorder was included, which by itself can serve as a limitation. The diagnosis of Childhood Apraxia of Speech was not considered in this study. It must also be noted that Dodd and colleagues (Dodd, 1995; Broomfield & Dodd, 2004) differentiate between 'Developmental Verbal Dyspraxia' (referred to as CAS in the study) and 'Deviant inconsistent phonological disorder' in terms of theoretical issues that are yet to be proved and issues around which controversies still exist such as:

a) At what level of programming or planning level the speech breakdown occurs,

b) Whether phonological awareness skills are affected in children with apraxia,

c) Amount of clarity and precision the two disorders exhibit,

d) Presence of oromotor or feeding difficulties etc.

Moreover, inconsistency is defined in different ways in the literature. Forrest (2003) noted that while some clinicians considered inconsistencies as variant productions across repetitions of the same sound sequence or word, others defined them as variations in production of a single sound across varying contexts. Additionally, some others considered a child's production to be inconsistent if a sound was produced differently in isolation versus in conversational speech.

Other than inconsistency in phoneme production noted in persons with Down syndrome, other issues suggesting deviant development have been pointed out by investigators, such as pattern of phonological development, and persistence of phonological errors in persons with Down syndrome. Smith and Stoel-Gammon (1983) in a longitudinal study, observed that the average rate of suppression per year for four phonological processes (final stop devoicing, initial cluster simplification, initial stop deaspiration, and final stop deletion) in children with Down syndrome was much lower when compared to typically developing children. They reported that in typically developing children, an average percentage change of about 38% occurred in reduction of the phonological processes showing a decline from 63% at 18-24 months to 25% at 30-36 months. In comparison, the mean percentage occurrence of the same processes in children with Down syndrome was 61% when the children were 3 years old, declining to 40% at the age of 6 years. This average change per year of 6% was minimal when compared with 38% for children developing typically. This suggested deviance in terms of the rate of phonological development in children with Down syndrome when compared to typically developing children.

Few other longitudinal studies of phonological development have been carried out in persons with Down syndrome. A study by Kumin, Councill and Goodman (1994) addressed the emergence of phonemes in the speech of 60 children with Down syndrome who were followed from 9 months to 9 years of age. Using emergence of phonemes as the criteria, they observed that though the overall pattern of acquisition was similar to that of younger typically developing children supporting previous research findings (Stoel-Gammon, 1980), certain phonemes did not seem to follow the general pattern in developmental sequence. A few notable differences were that (a) the voiceless palatal fricative /ʃ/ emerged considerably earlier than would be expected; (b) /f/ emerged somewhat later than /ʃ/; and (c) across the 60 subjects, age of emergence of /b/ ranged from 12 months to 8 years. The investigators noted that it was probably inappropriate to apply age of mastery norms to children with Down syndrome, as the hierarchy of appearance of phonemes in children with Down syndrome could be based on factors such as: (a) high visibility of articulators while producing the sound; (b) ease of production; (c) sequencing of sounds or complexity of sound combinations in a particular word; (d) length of words; and (e) variability of performance in children with Down syndrome. Also, the presence of hypotonicity in oral structures, and motor planning deficits could have had an impact on phoneme production of children with Down syndrome creating a different pattern of phonological development than is found in typically developing children.

Deviant aspects in development of phonology have also been reported in studies on older persons with Down syndrome. Sommers et al. (1988) observed that elimination of certain phonological processes and acquisition of certain distinctive features did not follow the same chronological pattern as the typically developing children. Processes such as final consonant deletion and cluster reduction of nasals had a high frequency of occurrence in spite of their being among the first to disappear in typically developing children. While a few features that were acquired earlier showed a low percentage of acquisition, a number of features that affected later-developing phonemes were acquired much later. They concluded that both delayed and deviant aspects of phonology are present in persons with Down syndrome. Deviant aspects were also reported by Van Borsel (1996) in older persons with Down syndrome who attributed errors such as decreased occurrence of distortions, and certain errors of addition to the presence of generalized hypotonia in these children. The increased occurrence of omission errors was attributed to 'less advanced' phonological development and not considered as a possible sign of deviant development.

To summarize, phonological acquisition of children with Down syndrome is reported to follow the same general pattern as documented for typically developing children, with four exceptions: (a) it is more variable; (b) it proceeds at a slower pace; (c) there is a higher proportion of idiosyncratic and/or atypical speech errors; and (d) there are differences in acquisition of suprasegmental aspects of speech, that are particularly apparent in running speech (Stoel-Gammon, 1997).

1.1.4. Phonological deficits in persons with Childhood Apraxia of Speech

Developmental trend in terms of phonology is not well documented in this disorder because of a lack of consensus on the temporal/linguistic markers and the use of compensatory strategies by children with this disorder (Shriberg, Aram, & Kwiatkowski, 1997a). Prevalence rates also vary because of age related variations in symptoms (Velleman & Strand, 1994). In addition, it becomes difficult to study the developmental trend since CAS may not be evident until remediation is evidenced (Lewis, Freebarin, Hansen, Iyengar, & Taylor, 2004). On the other hand, sometimes speech-sound disorders first diagnosed as CAS may be reclassified as phonological disorders during the course of the disorder. Lewis et al. (2004) studied three groups of children with CAS, isolated speech-sound disorders and combined speech and language disorders. These children were followed from pre-school to school age and assessed on measures of articulation, repetition tasks, oral motor functions and language abilities. The results indicated poorer school-age outcomes for the CAS group relative to both groups for most of the measures.

Phonological characteristics have been extensively studied in persons with CAS, but controversy surrounds the specific characteristics that define CAS (Nijland et al., 2002; Lewis et al., 2004). Numerous efforts (Stackhouse, 1992; Shriberg, Aram, & Kwiatkowski, 1997a, 1997b, 1997c; Davis, Jakielski, & Marquardt, 1998) have been made to formulate diagnostic criteria for this elusive disorder, but no standard set of criteria have been identified yet. While this debate goes on, the present study lists the characteristics from Childhood Apraxia of Speech without delving into the possibilities of these acting as diagnostic markers. The characteristics include:

- High rate of consonant omissions and substitutions (Crary, 1984b; Hall, Jordan, & Robin, 1993; Forrest & Morrisette, 1999; Nijland et al., 2002; Nijland et al., 2003; Lewis et al., 2004)
- Difficulties sequencing phonemes and syllables, including metathetic errors (Hall et al., 1993; Nijland, et al., 2002; Lewis et al., 2004)
- Unusual errors (Stackhouse, 1992; Hall et al., 1993; Velleman & Strand, 1994; Davis et al., 1998; Forrest, 2003; Lewis et al., 2004)
- Increased errors on motorically complex utterances (Stackhouse, 1992; Robin, 1992; Hall et al., 1993; Velleman & Strand, 1994; Forrest & Morrisette, 1999; Lewis et al., 2004)
- Vowel errors (Pollock & Hall, 1991; Hall et al., 1993; Walton & Pollock, 1993; Shriberg et al., 1997a, 1997b; Davis et al., 1998; Forrest & Morrisette, 1999; Nijland et al., 2003)
- Assimilatory errors or contextual substitution errors (Hall et al., 1993; Forrest & Morrisette, 1999; Nijland et al., 2003)
- Inconsistency in speech (Robin, 1992; Davis et al., 1998; Forrest & Morrisette, 1999; Nijland et al., 2002; Forrest, 2003; Nijland et al.; 2003)
- Increased nasality (Hall, Hardy, & Lavelle, 1990; Shriberg et al., 1997a, 1997b; Shriberg et al., 2003)
- Multiple errors or two- and three-feature errors (Yoss & Darley, 1974).

Hall et al. (1993) and Shriberg et al. (1997a, 1997b) have also delineated specific phonological errors such as voicing errors, cluster reduction, liquid simplification, palatal fronting, velar fronting, and stopping in persons with Childhood Apraxia of Speech. Other than phonological deficits, the speech of children with Down syndrome is also characterized by fluency problems that also contribute to their speech intelligibility.

1.2. Fluency deficits

Fluency deficits of the developmental nature have been described variously in literature as (a) cluttering that refers to a fluency disorder that is not stuttering and is characterized by rapid and / or irregular speech rate along with associated disturbances in language and / or attention; (b) disfluency that refers to fluent breakdowns in speech; (c) dysfluency or stuttering that refers to stuttered breakdowns in speech; and (d) non-fluency which is used when disfluencies and dysfluencies are not clearly delineated (Van Borsel, & Tetnowski, 2007). In the review of literature regarding fluency deficits that follows, terminologies used by investigators who have carried out the respective studies have been retained.

1.2.1. Prevalence of fluency deficits in Down syndrome

A higher prevalence of stuttering was reported in subjects with Down syndrome when compared to other developmental disabilities or with typically developing individuals (Van Riper, 1982). Stuttering was reported to occur in approximately 1% of typically developing individuals, amongst 10% of those with developmental disabilities, and in 45-53% of children with Down syndrome (Devenney & Silverman, 1990; Preus, 1990). Other reports of incidence of stuttering in persons with DS have been cited as 33% (Devenney, & Silverman, 1990) and 45% (Schlanger & Gottsleben, 1957). Evans (1977) also reported a higher incidence of stuttering among people with DS and carried out a detailed analysis of their speech. It was found that all characteristics of repetitions, prolongations, broken speech and interjections were present in persons with Down syndrome. Kumin (1994) observed that while difficulties with articulation and sequencing were perceived by parents from all age groups of children, fluency problems were observed only after the age of 5 years. Furthermore, 17% of all parents who responded to the survey reported stuttering in their children with Down syndrome. It is generally agreed upon that persons with Down syndrome exhibit the core characteristics of stuttering, such as, whole and part word repetitions, prolongations, and some tensions (Cabanas, 1954; Preus, 1973; Bloodstein, 1981; Van Riper, 1982). From an extensive review presence of stuttering in genetic syndromes, Van Borsel and Tetnowski (2007) conclude that while persons diagnosed with various syndromes including Down syndrome showed evidence of nonfluency patterns, not all of them would be considered stuttering.

It is also not clear if stuttering occurs more frequently in males than in females for the Down syndrome population as is the case for stuttering in the non-mentally retarded population (Van Borsel & Tetnowski, 2007). Evans (1977) found significantly more prolongations and blocks in male subjects than in female subjects and a similar but not significant trend for repetitions and interjections. However, Devenney and Silverman (1990), state that stuttering occurs to a similar degree in both sexes. A great deal more research is necessary before definite statements about the occurrence and prevalence of fluency disorders in Down syndrome can be commented on.

1.2.2. Types of fluency deficits in Down syndrome

The higher prevalence of disfluencies in individuals with Down syndrome has been attributed to linguistic influences (Willcox, 1988), to the point that some investigators call the disorder cluttering instead of stuttering (Cabanas, 1954), and some attribute it to impairments in the speech-motor control system (Farmer & Brayton, 1979; Devenney & Silverman, 1990). While the classical definition of stuttering includes sound-syllable repetitions and blocking (lack of vocalization associated with tension in the speech system, tremors, facial tics), cluttering is associated with speech rate, word repetition, and phrase revision and repetition (Miller & Leddy, 1998). Controversy continues to exist as to whether the non-fluencies of individuals with Down syndrome might be better described as cluttering, owing to the lack of awareness of their speech difficulties or as stuttering owing to the presence of anxiety and avoidance behaviours. The theoretical distinction between stuttering and cluttering even outside the field of mental abilities is difficult to delineate; the two disorders may not be separate pathologies as they share many characteristic features (Willcox, 1988). In persons with mental retardation, this distinction is even more difficult to make.

The argument that dysfluent speech is due to motor control impairments has been supported by investigators (Henderson, Morris, & Frith, 1981; Henderson, Morris, & Ray, 1981) who address non-speech motor co-ordination and timing deficits in people with Down syndrome (Miller & Leddy, 1998). Several other studies on laryngeal reaction time and vocal tracking behaviour involving dysfluent speakers also suggest that neural processing difficulties that negatively influence early stages of preparatory speech-motor control programming lead to specific speech-motor control impairments in stutterers (Dembrowski & Watson, 1991; Nudelman, Herbich, Hess, Hoyt, & Rosenfield, 1992). Otto and Yairi (1974) compared the disfluent speech patterns from spontaneous speech samples of 14 to 31 year old persons with Down syndrome with those of 15 to 32 year old typically developing persons. The investigators found that besides repeating parts of words and whole words more frequently, speakers with Down syndrome also had more 'dysrhythmic phonations'. These disruptions were postulated to be due to speech motor control impairments that were secondary to differences in the neurophysiological mechanisms of persons with Down syndrome.

Devenney and Silverman (1990) compared the degree of right-handedness in persons with DS to disfluencies in their speech in order to correlate the performance of persons with severe grade retardation and non-right-handedness. Conversational speech samples from 31 adults with Down syndrome with mental retardation between 30 to 57.5 years of age were analyzed in terms of syntax, vocabulary and numbers of disfluencies. Laterality was not found to be related to intelligence quotient (IQ) and persons who were right-handed had fewer dysfluencies than those who were non-right-handed. Moreover, greater dysfluencies were found to be associated with better language skills. Thus, the results suggested that speech dysfluencies could not be accounted for by general failures in comprehension or by reference levels of overall intellectual impairment. In another study by Devenney, Silverman, Balgley, Wall and Sidtis (1990), two groups of fluent and non-fluent speakers with Down syndrome were compared for simple and complex speech and manual motor tasks. Dysfluent speakers with Down syndrome were observed to be faster in simple manual tasks but slower on the complex tasks than the fluent speakers. The findings indicated that the etiology of the speech dysfluency did not reflect, in any simple way, a deficit in peripheral muscular control associated with articulatory movement (Devenney et al., 1990).

People with Down syndrome also present cognitive-linguistic impairments as well as gross, fine, and speech-motor impairments, and hence it is unlikely that only one specific and atypically functioning system explains the underlying basis for their dysfluent speech behaviour (Miller & Leddy, 1998). Word and phrase repetition and revision behaviours have been considered as evidence for word-finding problems in children with language-learning disabilities (German, 1992). Farmer and Brayton (1979) postulated that if poor intelligibility, frequent dysfluency and shorter vowel durations were related in persons with Down syndrome, speech patterns would resemble cluttering rather than stuttering. They based this hypothesis on previous studies on typically developing individuals in whom increase in vowel durations were shown to be related to lesser dysfluencies (Farmer & Brayton, 1979). They studied two groups of adults with Down syndrome matched for age, sex, hearing status and single-word articulation scores.

They demonstrated that the group with more frequent dysfluencies also had 'fairly good' single-word articulation scores, poor intelligibility in conversational speech, and shorter vowel durations. They concluded that the relationship between fluency and intelligibility in the dysfluent Down syndrome group might have served as indicators for the difference between stuttering and cluttering. Since 'normal' stutterers, who also had shorter vowel durations, did not demonstrate a noticeable loss in speech intelligibility, while dysfluent Down syndrome subjects demonstrated both, the loss of intelligibility was designated as characteristic of cluttering rather than stuttering. However, this premise was based on characteristics found in typically developing individuals and it is probably impractical to generalize this notion to persons with Down syndrome.

Willcox (1988) examined the premise of normal non-fluency in Down syndrome considering that in normally developing children, a certain amount of non-fluency is recognized as normal-non-fluency in the early stages of language acquisition (Bloodstein, 1981; Myers & Wall, 1981; Yairi, 1981; Van Riper, 1982). Since non-fluency in Down syndrome was also accompanied by deficits in language skills (Cabanas, 1954; Zisk & Bialer, 1976; Preus, 1973), these non-fluencies were hypothesized to correspond to normal non-fluency, a feature of their language age and competence. Willcox (1988) analyzed speech samples of five children with Down syndrome aged 10; 10 to 15; 1 years and five developmentally normal subjects in the age range of 2;0 to 2;8 years who were matched for language age with the Down syndrome group. Non-fluencies that occurred were correlated with semantic, grammatical and phonological features. It was observed that, although children with Down syndrome did not show any more non-fluency than their developmentally normal counterparts, significant differences did exist in terms of qualitative features. Children with Down syndrome repeated segments more than whole words and prolongations formed a large part of their non-fluencies unlike the typically developing children whose non-fluencies consisted mostly of whole-word repetitions. Most children with Down syndrome were more non-fluent in content rather than function words, at the beginning of clause constituents, and on all types of clause constituents and within such constituents in positions other than initial utterances. Children with Down syndrome also had increased frequency of non-fluencies as utterance length increased. Their non-fluencies were correlated with poor phonology and low intelligibility. Willcox (1988) concluded that the non-fluency in Down syndrome was rather different from that of normal subjects, not only in its nature and extent but also in terms of the language difficulties that underlie it.

Various reasons have been attributed to the high occurrence rate of disfluencies in persons with Down syndrome:

- An organic basis that suggested a disruption in the motor system of the left hemisphere that may or may not be specific to speech (Devenney & Silverman, 1990)
- Increased problems at the stages of ideation and formulation of an appropriate neurolinguistic plan (Willcox, 1988)
- A mismatch between an optimal speaking rate and the rate of generation of the component processes of speech as a consequence of a breakdown in the neural

organization between repetitive, somewhat automatic movements and complex movements requiring sequential planning (Devenney et al., 1990).

1.2.3. Fluency deficits in persons with Childhood Apraxia of Speech

There are very few studies that report similarities between apraxia of speech and stuttering (Byrd & Cooper, 1989). Similarities in the symptoms of CAS and stuttering have been postulated as related to central neurological deficits (Rosenbek, 1980). While neurological deficits have been suggested by numerous investigators in the past (Rosenbek & Wertz, 1972; Yoss & Darley, 1974; Ferry et al., 1975; Rosenbek, Messert, Collins, & Wertz, 1978; Blakeley, 1980; Crary, 1984b), no specific neurological basis for CAS has been identified yet (Velleman & Strand, 1994). Central neurological processing deficits have also been suggested as possible etiologic factors in persons with stuttering (Rosenbek, 1980; Kent, 1983; Andrews et al., 1983). Byrd and Cooper (1989) administered 'Screening Test for Developmental Apraxia of Speech' (Blakeley, 1980) on 15 persons with CAS, 16 persons with stuttering and 15 typically developing persons in the age range of 4-9 years. Statistically significant differences were found between the apraxic and stuttering groups only with respect to their scores on the articulation subtest. This was interpreted as supportive of suggestions that central neurological processing deficits in stuttering and CAS are common. While this finding is based on hypothetical constructs, and no other studies have compared these three groups, other reports of stuttering in CAS are also present (Aram, & Nation, 1982; Hall et al., 1993). Stuttering has even been considered as a CAS error type by others (Rosenbek & Wertz, 1972; Yoss &Darley, 1974).

2.0. Factors affecting speech production in persons with Down syndrome

Although many reasons for the speech difficulties in people with Down syndrome have been proposed, it is far from clear, which of the many possible factors are actually involved (Hamilton, 1993; Chapman, 1995; Dodd & Thompson, 2001). No single factor has been accounted for the complex communication problems seen in children with Down syndrome (Rosin, Swift, Bless, & Vetter, 1988). A number of researchers have attributed various causes for the deficit in productive language. The forthcoming review enumerates the causes attributed to productive language deficits in general and those related to phonological development in particular. Miller (1988) proposed four possible causal constructs to explain the asynchrony in language development (verbal comprehension being much better than expressive language) in persons with Down syndrome.

a) *Increase in frequency of middle ear infections:* These are often reported to be associated with delayed language acquisition in normal children (Downs, 1980; Brandes & Elsinger, 1981). Miller (1988) predicted that middle ear problems would lead to both comprehension and production deficits and that the timing of these deficits would be variable depending upon the frequency and duration of middle ear infections and severity of the hearing loss. Hence this may not be a likely reason to cause the language asynchrony.

b) *Deficits in motor co-ordination and timing:* This is said to have a negative impact on the speech production system including respiration, phonation, and articulation. Asynchrony due to motor in-coordination would be evident by the end of the first year of life when reduplicated sound patterns and word forms are expected. According to Miller (1988) these deficits would predict deficits in language production only, with comprehension developing at the same rate as other cognitive skill deficits.

c) *Environmental variables:* Variables such as decreased expectation from the performance of individuals with mental retardation can result in a 'learned incompetence' or a lack of appropriate experience (Coggins & Stoel-Gammon, 1982), inappropriate maternal interaction styles (Stevenson, Leavitt, & Silverberg, 1984), or increase in maternal directiveness (Cardoso-Martins, Mervis, & Mervis, 1985). These would predict deficits in both comprehension and expression, which would be evident early in development (Miller, 1988).

d) *Hemispherical asymmetry:* Studies on dichotic listening tasks have revealed that individuals with Down syndrome rely upon right hemisphere instead of left hemisphere for information processing, which is not optimally organized for sequential production of language due to an organic deficit (Chua, Weeks, & Elliot, 1996). This explanation was based on the model proposed by Elliott, Weeks and Elliott (1987). Miller (1988) reasoned that this factor would predict deficits in either comprehension or production, which would be evident at the time of the child's development when comprehension and production of first words are expected.

Of the four causal constructs, two of them that would most likely predict the asynchrony in language development include deficits in motor in-coordination and hemispherical asymmetry, but neither of these hypotheses can fully account for the asynchrony in language development (Miller, 1988). This is because the cerebral specialization hypothesis does not explain why some children are affected and some children are not. While the speech motor deficit hypothesis does account for this variability, these deficits cannot be identified prior to the period of single word production. Stoel-Gammon (1997, 2001) listed the following factors that influence the phonological development of children with Down syndrome:

a) *Hearing status/Hearing loss:* Early and recurrent otitis media was observed in a large numbers of children with Down syndrome (Balkany, D., 1980; Balkany, T., 1980; Dahle & McCollister, 1986; Downs & Balkany, 1988). More recently, Lynch, Oiler, Steffens and Buder (1995) reported that of the 13 infants with Down syndrome studied, six of them displayed a hearing loss of 25-40 dB.

b) *Differences in anatomy and physiology of the oral mechanism:* The reported (Miller & Leddy, 1998; Leddy, 1999) differences include: (i) the vocal folds, influencing voice quality; (ii) structure of the oral cavity (a high palatal vault) and tongue size in relation to oral cavity, influencing articulation, particularly production of lingual consonants; (iii) weak facial muscles, limited lip movement, affecting production of labial consonants and rounded vowels; (iv) general hypotonicity affecting lip and tongue movements in particular. Any one of these oral motor problems is likely to influence speech motor development and have a negative impact on the articulatory and phonatory abilities of children with Down syndrome.

c) *Input or language-learning environment:* Nature of linguistic input that children with Down syndrome receive was reported as one of the factors likely to affect phonological development in these children. Research indicated that input from adults was inadequate for the vocal/verbal abilities of children with Down syndrome. The type of interaction style between caregivers and children with Down syndrome revealed numerous differences when compared to that with typically developing children. However, Rosenberg and Abbeduto (1993) disagreed and stated that little evidence of a causal relationship existed between features of adult input and acquisition.

d) *Perceiving and encoding speech:* The ability to perceive, store, and retrieve phonological representations is essential for the production and comprehension of speech (Fowler, 1990). Difficulties in these areas are reportedly associated with deficits in speech and language development (Stoel-Gammon, 1997). Fowler (1995) observed that in children with Down syndrome, a strong relationship existed between 'basic' measures of articulation, such as accuracy of production and verbal memory. Studies by Dodd (1975, 1976, 1995), and Dodd and Leahy (1989) also associated greater problems in encoding of speech for children with Down syndrome than in mental age matched typically developing children and those with mental retardation.

Dodd and Thompson (2001) enumerated several causes for speech difficulties observed in persons with Down syndrome and these include:

1) *Protruding tongue:* A protruding tongue reportedly hampers articulation, but surgical reduction in the size of the tongue did not been prove to have any effect on speech intelligibility (Parsons, lacono, & Rozner, 1987).
2) *Hearing problems:* Dodd and Thompson (2001) hypothesized that even mild fluctuating hearing loss could affect speech intelligibility. While no studies were carried out to confirm this, Dodd and Thompson (2001) also postulated that children with Down syndrome may rely more on visual information, and fail to develop auditory attention as a result of hearing loss.
3) *Hypotonia:* It reportedly affects speed and precision of speech movement.
4) *Chronic upper respiratory tract infections:* Blockage of nasal cavity by mucus is reported to lead to mouth breathing and lack of nasal resonance (Rondal & Edwards, 1997) causing problems in speech intelligibility.

Amongst the reasons put forth to explain difficulties in speech production in various sources, the ones highlighting prelinguistic development and language learning environment have not been accepted as factors that affect the speech production in persons with Down syndrome. Other factors including hearing problems, motor inco-ordination, differences in anatomy and physiology and hemispheric asymmetry have been recognized as likely factors causing speech production problems in Down syndrome. However there are varying reports and no one factor has been regarded as the sole cause for the speech production problems. For example, Stoel-Gammon (1980) concluded that since children with Down syndrome were capable of producing all phonemes although not in all positions of the word, it would be difficult to ascribe the errors to abnormalities of the oral structures.

The present study investigates two of these aspects:

- Differences in anatomy and physiology in the oral structures of persons with Down syndrome
- Motor inco-ordination i.e. presence of oral and verbal apraxia.

Addressing this issue, Hamilton (1993) stated that three main types of speech difficulties are possible in persons with Down syndrome: dysarthria (due to macroglossia and muscle weakness), dyspraxia (referred to as CAS in the study) and phonological delay/disorder. Electropalatographic data was used to evaluate the type of speech problems in three young adults with Down syndrome. The study used existing EPG data of normal and disordered speech to look for common patterns in the Down syndrome sample and compare them with the obtained results. Results revealed evidence for breakdown both in the ability to move the tongue and lips in order to articulate speech sounds accurately and in the ability to select, plan and sequence the sounds needed. In addition, phonological difficulties were also found. It was thence concluded that speech difficulties experienced by people with Down syndrome were complex and a breakdown is noticed at all levels.

3.0. Oral motor deficits in persons with Down syndrome

3.1. Oral motor, oral sensory and postural control deficits

Individuals with Down syndrome have skeletal and muscular systems that differ from those without Down syndrome (Miller & Leddy, 1998; Leddy 1999) and these differences are reported to affect speech production (Yarter, 1980; Miller, 1988; Rast & Harris, 1985). Individuals with Down syndrome are reported to have oral motor difficulties such as feeding problems and low muscle tone, in addition to motor planning difficulties (Kumin, 2002).

Persons with Down syndrome are also reported to have a small oral cavity probably because of a small skull, missing or poorly developed midfacial bones, and a small but wide mandible (Sommers et al., 1988; Miller & Leddy, 1998; Stoel-Gammon, 2001). The hard palate has been described variously as being short and narrow (Sommers et al., 1988), V shaped stair configuration (Desai, 1997), and high vault type (Stoel-Gammon, 1997). Individuals with Down syndrome have also been reported to demonstrate Angle's class III malocclusions (i.e. lower teeth are anterior to the upper teeth) with prognathism (i.e. protruded lower jaw) (Sommers et ah, 1988; Borea, Magi, Mingarelli, & Zamboni, 1990; Desai, 1997).

Most investigators have noted tongue protrusion, but there are differing opinions about whether the tongue is enlarged (Kavanagh, 1995; Nowak, 1995). While some have reported that the tongue is enlarged (i.e. true macroglossia) (Sommers et al., 1988; Stoel-Gammon, 2001), others have found an average sized tongue. However, it was observed that the combination of a small cavity and a normal sized tongue (i.e. relative macroglossia) may limit the distance and range of movement of the tongue (Miller & Leddy, 1998). Children with Down syndrome are also reported to have a posterior tongue carriage, and a muscular system characterized by absent and extra muscles in the facial region (Stoel-Gammon, 2001). Fissures in tongue have also been reported by a few researchers (Sommers et al., 1988; Barnes, Roberts, Mirrett, Sideris, & Misenheimer, 2006). Open mouth posture (i.e. mouth habitually open at rest) may result due to the presence of small oral cavity, normal-sized tongue, hypotonic lip and jaw muscles, and lax ligaments (Rynders & Horrobin, 1996) in the temporomandibular joint. Other factors that are reported to contribute to open mouth posture are frequent upper respiratory tract infections, enlarged tonsils and adenoids that may cause the need to breathe through the mouth (Kavanagh, 1995).

Most children with Down syndrome are reported to exhibit hypotonia or low muscle tone, decreased strength, and hyperextendable joints (Miller & Leddy, 1998; Kumin & Bahr, 1999; Dykens, Hodapp, & Finucane, 2000). Share and French (1993) reported that the incidence of hypotonia is over 95% in children with Down syndrome. Hypotonia is also reported to lead to many other functional problems such as open mouth posture, drooling, difficulties with lip closure, angle of mouth pulled down, tongue protrusion at rest, aspiration related to hypotonia of the pharyngeal musculature, and pharyngeal incoordination (Frazier & Friedman, 1996; Spender et al., 1996; Desai, 1997). Due to low muscle tone and difficulties with neuromotor control, muscles of the oral mechanism are reported to be poorly dissociated. In a study of 50 children with Down syndrome, Borea et al. (1990) observed functional difficulties including mouth breathing (96%), chewing difficulties (66%), and bruxism or tooth grinding (45%).

Spender et al. (1995) studied three twin pairs (1 child with Down syndrome and 1 nonaffected child in each pair) in the age range of 11 and 27 months and found that children with Down syndrome demonstrated excessive tongue protrusion, inadequate lip closure, and poorly controlled jaw function. Another study by Spender et al. (1996) compared oral motor development of 14 children with Down syndrome (aged 11 to 34 months) to that of 58 mental-age matched typically developing children (aged 12-17 months). Other than poor jaw control and intermittent lip closure, they also noted arrhythmic tongue movements. Barnes et al. (2006) compared oral structure and oral motor functioning of boys with Down syndrome (4;3 to 15;9 years), fragile-X syndrome (2;9 to 14 years) and typically developing children (2;5 to 6;6 years). Both groups of boys with disorders scored lower than typically developing boys on oral structure, some oral function tasks, and all speech function tasks. Unlike the other two groups, boys with Down syndrome scored lower on speech function than on oral function tasks. Boys with

Down syndrome had the most atypical oral structure with respect to lips, tongue, and velopharyngeal structure amongst all three groups. High, narrow palates and macroglossia were also observed in children with Down syndrome. Despite the presence of atypical tongue structure, persons with Down syndrome showed no significant difference when compared to typically developing children in terms of tongue function for oral movements. This finding may be evidence to the observation that atypical structure of an articulator may not necessarily hinder adequate function. However, tongue movements for speech were more affected in Down syndrome than the other two groups.

Oral hyposensitivity and hypersensitivity have also been reported in young children with Down syndrome (Frazier & Friedman, 1996). 'Rejection of age-appropriate food textures; reduced acceptance of food tastes, temperatures or smells; picky eaters; aversive or exaggerated response to touch in/or around the mouth; hyperactive gag response; aversion to brushing teeth; and lack of age-appropriate mouthing of toys/hands' were reported as some of the characteristics of oral hypersensitivity. Characteristics of oral hyposensitivity included 'poor or no awareness of food on lips, slow registration of food in mouth, pocketing of food, and stuffing of mouth' (Frazier & Friedman, 1996).

Persons with Down syndrome are reported to have difficulties with postural control that have been attributed to delays in the attainment of motor milestones in these children (Cobo-Lewis, Oiler, Lynch, & Levine, 1996). Possible neuromuscular links between postural control and rhythmic behaviours directly affect motor and vocal control (Cobo-Lewis et al., 1996). Postural control related to hypotonia in children with Down syndrome can also lead to insufficiency of co-contractions and balance reactions, reduced proprioception, and increased joint mobility (Lauteslager et al., 1998). Clinically, difficulties such as achieving and maintaining trunk, shoulder, neck, head, and jaw stability as well as dissociated movements of the jaw, lips and tongue have been cited in literature (Kumin & Bahr, 1999). Even the development of feeding, eating, drinking and speaking are claimed to be directly influenced by the reduced postural tone (Kumin & Bahr, 1999) since 'the development of basic motor abilities takes place under the influence of reduced postural tone' (Lauteslager et al., 1998).

3.2. Factors related to oral motor deficits that affect speech production

Abnormalities in the anatomy and physiology of the oral mechanism, such as (a) deficient bone growth in the head and face, (b) hypotonia of the speech muscles, and (c) reduced space in the oral cavity, have been reported to have an impact on speech production in this population (Smith & Stoel-Gammon, 1983; Spender et al., 1995, 1996; Miller & Leddy, 1998; Dykens et al., 2000; Dodd & Thompson, 2001). In addition, speech resonance qualities and range of motion of articulators are reported to be affected due to smaller skulls, underdeveloped maxilla bones, and smaller, wider mandibles. Atypically large tongues on the other hand are hypothesized to reduce lingual motility for speech production, while hypotonic facial muscles could limit lip movements necessary for consonant and vowel production (Stoel-Gammon, 1997; Miller & Leddy, 1998). Kumin and Chapman (1996) stated that while there may be common patterns of oral motor issues such as low postural tone and resultant postural instability, each child might exhibit one or more of the above concerns. Low postural tone is reported to result in difficulties or poor performance of more refined movements in the hands and the mouth and can also reportedly cause problems in respiration. Other oral motor problems that were reported to affect speech production are listed as follows:

a) Low oral muscle tone/jaw instability.
b) Difficulties with responses to sensory input.
c) Difficulties with the integration of sensory feedback in the production of an adaptive response.
d) Difficulties with oral movement for feeding/eating.
e) Difficulties with oral movement for speech production.

Stoel-Gammon (1997, 2001) have listed differences in anatomical and physiological structures in persons with Down syndrome that account for poor production and they are as follows:

a) Vocal folds, influencing vocal quality.
b) Structure of the oral cavity (a high palatal vault) and tongue size in relation to oral cavity, influencing articulation, particularly production of lingual consonants.
c) Weak facial muscles, limiting lip movement that affects production of labial consonants and rounded vowels.
d) General hypotonicity affecting lip and tongue movements in particular.

In a survey of parents using questionnaires, Kumin (1994) tabulated parents' views on oral motor problems faced by children with Down syndrome. Of the 937 parent responses, 28% of the parents indicated that their children had difficulty with tongue-thrusting behavior, 16% indicated difficulty with weak facial muscles, another 16% indicated difficulties in chewing, and 14% indicated difficulties in swallowing. Additionally, 58% of parents of the 19 adults, whose responses were analyzed, reported tongue thrusting to be a problem. Kumin (1994) pointed out that given the consistency in presence of tongue thrust in younger age groups, a higher percentage of tongue thrust in older persons with Down syndrome may lead to losing teeth or an edentulous condition.

4.0. Oral and verbal praxis in persons with Down syndrome

4.1. Definitions and historical background

Most studies on speech abilities have examined speech sound errors, distinctive feature errors, and phonological skills of individuals with Down syndrome. Some studies also examined the speech intelligibility problems and disfluencies. There are few studies however those address the speech praxis deficits in persons with Down syndrome. Praxis refers to the generation of volitional movement patterns for the performance of a particular action. It is the ability to select, plan, organize, and initiate a motor pattern for any activity (Nicoloff, 2004). 'Oral praxis' refers to the generation of volitional movements for performing oral movements using the lips, tongue and jaw. Clumsy and awkward oral / nonspeech movements carried out on examiner's command suggest 'oral apraxia'. It includes the inability to puff cheeks, blow a whistle, kiss, protrude the tongue etc. On the other hand, 'verbal praxis' refers to the ability to generate voluntary movements for speech. It includes the ability to select, plan, and organize motor patterns for the production of sounds, syllables, words and sentences. A breakdown in verbal praxis leads to 'verbal apraxia'. It affects the programming of the articulators and rapid sequences of muscle movements that are required for speech sound productions leading to Childhood Apraxia of Speech (CAS). Addressing this issue in Down syndrome assumes importance because of the type of errors in production reported in these children. In the past, numerous investigators attributed the increased errors in speech production in persons with Down syndrome to 'motor disability' (Dodd, 1976), 'sequential processing deficits' (Rosin et al., 1988), 'motor preplanning' (Sommers et al., 1988), and 'motor planning deficits' (Hesselwood, Bray, & Crookston, 1995).

In a study comparing persons with Down syndrome and those with mental retardation without Down syndrome, Dodd (1976) observed that the group with Down syndrome exhibited more inconsistent errors. They also exhibited fewer errors on imitation than in spontaneous naming tasks and this led Dodd (1976) to conclude that difficulties in programming of the speech movements could have partly caused the articulatory deficit in children with Down syndrome.

Rosin et al. (1988) studied the communication profiles often male adolescents with Down syndrome (DS) and compared them with the same number of children from three other control groups of (a) mental age matched children with mental retardation

(MR), (b) subjects (Ni) with normal intelligence with mental ages comparable to DS and MR groups, (c) chronological age matched adolescents with normal intelligence (N2). Mean length of utterance, comprehension of syntax, single word articulation, selected diadochokinetic tasks, and some aerodynamic tasks were significantly more affected in the group with Down syndrome. They also had more difficulty with intelligibility as demands for sequencing increased. Among the diadochokinetic measures, the group with Down syndrome required significantly more cueing to produce /pataka/. Amongst measures of intra-oral pressure, they had more variable values when producing /papapapa/. The investigators concluded that difficulty with processing sequential information is presented by adolescents with Down syndrome in both production and comprehension and that this was a possible explanation for the significant intelligibility problems of the DS group.

A careful observation of few of the errors reported in literature leads one to suspect that fundamentally, these children could be having problems in processing and executing speech with appropriate 'praxis' dimension, and hence this leads to CAS. Some of the reported errors that can be explained on the basis of poor praxis control of speech are as follows:

- Vowel errors (Van Borsel, 1996; Layton, 2001)
- Speech sound omissions (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon, 1983; Sommers et al., 1988; Van Borsel, 1988, 1996; Layton, 2001)

- Fluency deficits (Otto & Yairi, 1974; Farmer & Brayton, 1979; Willcox, 1988; Devenney & Silverman, 1990; Dembrowski & Watson, 1991; Nudelman et al., 1992; Miller & Leddy, 1998)
- Better scores on single-word articulation scores that conversational speech scores (Farmer & Brayton, 1979; Rosin et al., 1988).
- Speech-segment-timing deficits (Farmer & Brayton, 1979)
- Voicing errors (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon, 1983; Bleile & Schwarz, 1984; Van Borsel, 1988, 1996; Stoel-Gammon, 1997, 2001; Kumin & Adams, 2000)
- Atypical deficits in morphosyntax when compared to semantics and pragmatics. (Miller & Leddy, 1998; Chapman & Hesketh, 2000)
- Difficulty in maintaining adequate intraoral pressure (Miller, & Leddy, 1998; Kumin, Von Hagel, Bahr, & Hillis, 2001)
- Speech prosody and rhythm errors (Shriberg& Widder, 1990; Hesselwood etal., 1995)

Historically, children with Down syndrome were not identified as having CAS in part, due to the original definition of CAS as inclusive of only those subjects who have (a) normal intelligence, (b) absence of hearing loss, and (c) absence of muscle weakness or paralysis (Kumin & Adams, 2000). Kumin and Adams (2000) observed that definition of CAS was not generalized beyond the original participant groups because children with Down syndrome are reported to frequently have hearing problems, mild to moderate retardation and low muscle tone. These are probably the reasons why there have been few reports of investigations specifically addressing the issue of oral and verbal praxis studies.

4.2. CAS in persons with Down syndrome

Various methods have been used to evaluate CAS in Down syndrome. Few studies compared characteristics observed in Down syndrome with those found in typically developing persons with CAS (Ferry et al., 1975; Kumin & Adams, 2000), others used electropalatography (Hamilton, 1993) and few have conducted parental surveys (Kumin, 1994, 2003). Oral praxis deficits have also been evaluated (Elliott et al., 1990) to study hemispheric asymmetry in Down syndrome.

A study by Ferry et al. (1975) was one of the earliest to evaluate sixty institutionalized persons with mental retardation including two persons with Down syndrome for the presence of developmental verbal dyspraxia (referred to as CAS in this study). The analyses included assessment of auditory comprehension, conversational and expository speech, verbal and non-verbal oral agility, visual naming, and symbol and word naming and recognition. The diagnoses of CAS were made based on characteristics such as, significant delay in speech development, disproportionately high receptive language level, presence of groping, inconsistent omissions, substitutions and distortions. 60% of the individuals were reported to have orofacial dyspraxia, but other details with respect to characteristics of CAS were not provided. Furthermore, the subjects with Down syndrome were not analyzed separately.

Elliott et al. (1990) reported oral praxis deficits in adults with Down syndrome. The investigators compared 16 persons with Down syndrome with 14 persons having 'undifferentiated' mental retardation on single-, two-, and three-element oral tasks using verbal instruction and visual demonstration. They concluded that persons with Down syndrome exhibited better scores on oral praxis tasks when visual demonstration was provided but they did not perform as well as the control group on verbal instructions. The reason for this dissociation in performance between the two tasks was explained as due to the difficulty in translating verbal instructions into the appropriate response in persons with Down syndrome. This reasoning was based on a model developed by Elliott et al. (1987) that hypothesizes dissociation between the left and right hemispheres in terms of specialization of skills involving speech production and speech perception, hi short, hemispherical asymmetry as shown by studies on dichotic listening was revealed in individuals with Down syndrome. Persons with Down syndrome rely upon right hemisphere instead of left hemisphere information processing systems that are not optimally organized for sequential production of language due to an organic deficit (Chua etal., 1996).

Hamilton (1993) evaluated tongue movements of three young adults with Down syndrome aged 17 to 20 years by using electropalatography (EPG) to analyze whether their speech resembled that of persons with dysarthria, apraxia or phonological disorder. Various tasks including imitation, naming and reading of 54 target words; and DDK measures were compared to the data obtained from one non-disabled adult. Patterns observed from previously existing EPG studies on children with apraxia and dysarthria were compared with the findings of this study. Patterns such as (a) increased tongue-palate contact, (b) undershoot of velars, (c) overshoot of fricatives, (d) absence of auditory difference between /s/ and /ʃ/ and (e) absence of coarticulatory patterns in consonantal clusters were considered to be indicative of dysarthria. Patterns of EPG observed in children with apraxia were also found in these subjects, such as (a) presence of long closure durations, (b) slow approach and release phases for closures, (c) abnormally long transitions between different elements of consonantal clusters, (d) difficulty in repeating CV sequences in DDK, (e) erratic and arrhythmic production of CV sequences, and (f) asymmetry and variability in articulation of fricatives. Developmental phonological patterns such as final consonant deletion, consonant harmony, fronting, stopping of fricatives, and cluster reduction were also noted. This study is one of the few that has used objective methods to evaluate the presence of underlying processes causing speech intelligibility problems in persons with Down syndrome. However, conclusions made on the basis of previous data without matching variables such as age may have served to make the comparisons erroneous.

McCann and Wrench (2007) have also reported EPG findings in persons with Down syndrome using DDK tasks. They studied 12 persons with Down syndrome in the age range of 10;8 to 18;7 years and compared them with four typically developing children of ages 5;4 to 7;1 years. The DDK tasks were evaluated for rate (at six predetermined rates) and accuracy using an imitation task aided by a metronome. An attempt was made to objectify the tasks as much as possible for ease of assessment and to evaluate the presence of dyspraxia (referred to as CAS in this study). It was found that while persons with Down syndrome did not differ from the typically developing children in terms of rate, they differed in terms of accuracy especially for the sequential tasks. The findings of sequencing errors in DDK tasks have also been reported in persons with CAS by Thoonen, Maassen, Wit, Gabreels and Schreuder (1996). The study by McCann and Wrench (2007) suggested the importance of assessing persons with Down syndrome using DDK tasks in a more objective manner. However, the comparison group was not matched in terms of mental age due to difficulties in using EPG plates in very young children.

Some studies evaluated CAS in persons with Down syndrome by analyzing parental perceptions. In a survey of over 1000 families that Kumin (1994) conducted, 48 to 72% of parents reported that their children presented signs of motor planning problems, including difficulties in sounds, making sound reversals and sound errors. In another survey of 1500 families (Kumin, 2003), carried out to determine whether apraxia is a widespread problem in individuals with Down syndrome, it was revealed that although most children exhibited symptoms of apraxia, only 16% of the parents had been given that diagnosis. However, 61% of families were told that the children had problems such as low muscle tone. It was evident that dysarthria due to oral motor deficits that is more commonly known amongst clinicians and CAS is still an unknown or rather; less used a term in relation to Down syndrome.

The only study that investigated CAS in children with Down syndrome using an assessment tool to identify motor speech disorders is one by Kumin and Adams (2000). Seven children in the age range of 5.7 to 13.4 years with Down syndrome were evaluated to determine whether speech characteristics of persons with Down syndrome resembled those of typically developing children diagnosed with CAS. For each participant, a parent questionnaire, connected speech sample, and an apraxia test called 'The Apraxia Profile' (Hickman, 1997) were completed. Results from the questionnaire revealed that the behaviours found in these children are also typically seen in children with CAS. For example, 71% of the children were found to have cooed or babbled very little, 86% were slow to begin speech and 100% reportedly appeared to understand better than they could produce speech. In addition, most of the communicative behaviors included gestures and 71% of the children were reportedly frustrated at not being understood. The results also disclosed a numbers of characteristics of CAS found in children with Down syndrome as follows:

- Voicing errors.
- Inconsistent errors, depending on the phonemic environment.
- Increased difficulty in volitional tasks i.e. voluntary oral movements than automatic oral movements.
- Better speech intelligibility when producing familiar words or phrases.
- Superior receptive language compared to expressive language.
- Poor syntax or morphology.

- Reduced speech intelligibility with increased length of utterance, especially in unknown contexts.
- Slow progress in speech therapy.
- Increased use of gestures in communication.
- Child's speech needs to be interpreted with the help of family members.
- Increased occurrence of sound omissions.
- Presence of perseverative articulatory errors.
- Presence of anticipatory articulatory errors.

The results from the Apraxia characteristics checklist in "The Apraxia Profile" revealed that scores from the top ten characteristics commonly found in children with DS ranged from 40%-60%. Three children were rated as having 'mild' apraxia, one was rated as having 'very mild' apraxia, two of them showed 'moderate' apraxia and one had 'moderate to mild' apraxia. A variety of different errors were noticed in these children in a range of combinations. For example, one child exhibited hypernasality with a mild apraxic component; another exhibited difficulty only in the more complex tasks, such as, sequencing and altering of rate of movements. The age range of the subjects studied was very wide i.e. 5;7 to 13;4 years of age and this might have added to the variability in the characteristics exhibited by the children. Although this study was done on a small number of subjects, it was one of the first to administer a speech motor assessment tool on children with Down syndrome to evaluate the presence of CAS. The test however included norms established in typically developing children and not specifically meant for children with Down syndrome. Another drawback of the study was the criteria of selection of participants that allowed for inclusion of only those children with Down syndrome with poor speech intelligibility. Evaluation of characteristics of CAS regardless of their speech intelligibility problems would provide a more comprehensive picture of presence of CAS in children with Down syndrome. Characteristics such as, groping (Crary, 1984b, 1993; Robin, 1992; Hall et al., 1993; Ozanne, 1995; Shriberg et al., 1997a, 1997c; Forrest & Morrisette, 1999; Nijland et al., 2002; Forrest, 2003; Nijland et al., 2003; Lewis et al., 2004) and fluency problems (Aram & Nation, 1982; Byrd & Cooper, 1989; Hall et al., 1993) that are also characteristic of persons having CAS were not commented on.

CAS in Down syndrome was also evaluated using phonological process analysis by Rupela and Manjula (2007, June). Thirty 11 to 15 year old persons with Down syndrome were compared with two control groups viz. mental age matched persons with mental retardation (without DS) and typically developing children. Phonological processes suggestive of praxis deficits such as high degree of omissions, voicing, vowel errors, sequencing, idiosyncratic errors and errors concerning nasality were analyzed. It was found that persons with Down syndrome showed significantly greater errors suggestive of praxis deficits when compared to the control groups suggesting greater praxis deficits in persons with Down syndrome. Correlation between frequency of occurrence of phonological errors and complexity of utterances was also evaluated. Words were rated on a 7-point rating scale on the basis of their length, numbers and types (geminated vs. non-geminated clusters) of clusters. This rationale was based on a previous study on phono tactic development by Rupela and Manjula (2006) that revealed that geminated clusters and disyllabic words were acquired before non-geminated clusters and multisyllabic words in typically developing children. Numbers of errors per word were tabulated irrespective of type of errors and then statistically correlated with complexity of errors. It was found that as complexity of words increased, the numbers of errors increased in all three groups of individuals. The strength of correlation however was highest for persons with Down syndrome when compared to the other two groups and it was lowest for the typically developing children. However, this finding by itself was not suggestive of praxis deficits. It needs to be reviewed with more stringent controls over complexity rating probably by using the same type of consonants across varying complexities of length and clusters.

Phonotactic patterns in seven 11 to 15 year old, Kannada speaking children with Down syndrome were analyzed to explore the possible presence of CAS by Rupela and Manjula (2007). The phonotactic patterns of persons with Down syndrome were compared to those of persons with mental retardation (without DS) and mental age matched typically developing children. Both conversational and imitated speech samples from all participants were studied. The results suggested that children with Down syndrome showed a higher percentage of earlier acquired and simpler phonotactic patterns than the ones that are acquired later in typically developing children. The types and percentage occurrences of the patterns used by children with MR (without DS) had a more mature phonotactic repertoire than that of children with Down syndrome. A target analysis of conversational speech samples was also carried out to evaluate whether the participants attempted different phonotactic patterns. The results of target analysis revealed no significant differences in the syllable shapes, and geminated and non-geminated clusters across the three groups. Additionally, no differences between the two groups of disorders in terms of multisyllabic words and three-sound clusters were observed. It is possible that the two groups with disorders attempted similar word shapes and cluster patterns when compared to the typically developing children. The authors believe that phonotactic deficits such as those revealed in the study indicated the presence of CAS in persons with Down syndrome.

While there is abundant research on children with Down syndrome and on children with CAS, there are few studies that examine the co-occurrence between the two disorders (Kumin & Adams, 2000). The diagnosis of CAS is important in order to adequately formulate assessment and treatment programs for persons with Down syndrome. Over the years, issues relating to therapy for improvement of speech production in persons with Down syndrome have focused on the oral motor (dysarthric) point of view and have generally failed to address the motor planning difficulties seen in children with Down syndrome (Kumin & Adams, 2000). Speech intelligibility difficulties have often been viewed, assessed and treated exclusively from a dysarthric (oral motor) perspective (Swift & Rosin, 1990; Chapman, Seung, Schwarz, & Kay-Raining Bird, 1998; Stoel-Gammon, 2001; Dodd & Thompson, 2001), when a dysarthric approach may address only one part of the difficulty (Kumin & Adams, 2000).

5.0. The presence of CAS in persons with Down syndrome

So far, the review focused on factors that could affect productive language skills in persons with Down syndrome and the kind of speech related problems that these factors give rise to. Speech production errors were described in terms of phonological problems and fluency deficits whose presence reflected on the poor speech intelligibility. These viewpoints then paved way for arguments that the speech errors may be due to speech praxis difficulties. It is important to address oral and speech praxis deficits in persons with Down syndrome, since according to motor learning principles, speech production skills develop through learning and experience (Caruso & Strand, 1999).

Early movements such as those involved in crying, sucking and feeding serve as precursors to movements and skills needed for certain speech sounds (Kumin & Adams, 2000). Netsell (1981) proposed stages of motor control for speech that take place during the normal development of children. First, the child develops motor control for spatial aspects, then spatial-temporal co-ordination and finally adult-like timing of motor control, including the anticipatory movement gestures of co-articulation. Netsell (1981) suggested that the most sensitive period for acquisition of speech motor control is from 3 to 12 months suggesting that fundamental movement routines for speech in children are established early.

During the initial stages of development, the child needs to use very controlled processing in order to manage this complex motor skill of speech production. Fletcher

(1992) views early speech learning as an integrative process in which "auditory, vocal tract and visual sensations are extracted in parallel and linked together to define articulatory gesture perception at every level of representation". As children develop and use speech, some of these movements become well practiced or habituated and more practiced movement gestures require less conscious processing (Caruso & Strand, 1999). During development, children acquire strong motor plans and using these motor plans, they can produce rapid, precise, sequenced speech, almost automatically (Caruso & Strand, 1999).

It is important to have adequate auditory, kinesthetic and proprioceptive input and integration in order for accurate motor plans to develop (Caruso & Strand, 1999). Kumin and Adams (2000) argued that while speaking, the speaker receives tactile and kinesthetic feedback in relation to the position of his or her articulators and auditory feedback to simultaneously evaluate the "correctness" of the utterance. However, the same sensory motor cues must also be processed before speech production can occur (i.e. afferent input) (Caruso & Strand, 1999). It is necessary to process all the incoming sensory input in order to develop the motor plans needed for motor speech acts (Kumin & Adams, 2000).

Caruso and Strand (1999) stated that developmental motor speech disorders occur because of processing impairments involving motor skill and because children with motor speech disorders are still in the process of acquiring linguistic and motor skill. A motor impairment at any level is likely to affect the ongoing acquisition of phonology and other linguistic skills. Neuroanatomical, neurophysiologic and neuromuscular changes over the course of development influence early word production. Speech development takes place due to a combination of cognitive, linguistic, neuromaturation (motor and sensory) of the vocal apparatus. If the natural development of these factors is impaired or delayed, speech acquisition can be affected.

Persons with Down syndrome have distinct features in their nervous systems that serve to delay the neuromaturational changes required for speech development. The differences in nervous systems of persons with Down syndrome include anatomical differences in the central and peripheral nervous system, reduced brain size and weight, smaller and fewer sulci, narrower superior temporal gyrus, fewer cortical neurons, decreased neuronal density, delayed neuronal myelination; abnormal dendrite structures; and altered cellular membranes (Yarter, 1980; Rast & Harris, 1985; Miller, 1988; Miller &Leddy, 1998; Leddy, 1999).

Such deficiencies in neuroanatomical structures can lead to developmental delays in both motor (Lauteslager et al., 1998) and speech (Lenneberg, 1967; Miller & Leddy, 1998; Chapman & Hesketh, 2000) milestones in persons with Down syndrome. This leads to neuroanatomical, neurophysiologic and neuromuscular delays and impairments in the development of the vocal apparatus and musculature. Oral motor problems that occur due to hypotonia, small oral cavity and macroglossia may also add to these delays. Because these delays occur during the early developmental period, the effect may remain until later due to which the child is likely to have motor learning problems that can lead to praxis difficulties.

Additionally, many infants and young children with Down syndrome have hypo- and/or hyper-sensory issues such as those involving tactile responsiveness. During the early stages of development, the infant develops an internal model of the vocal tract based upon perceptual, auditory and somatic sensory consequences (Gracco, 1995). Hence, the learning phase is highly dependent on sensory stimulation from all possible sources: visual, auditory, and kinesthetic. The different modalities provide different but associated information to the child that needs to amalgamate and establish mappings between multimodal sensory information and various neuromotor processes underlying adult speech production. After the development is complete, these sensorimotor transformations that allow rapid and direct mappings between sensory modalities and levels of motor output are presumably acquired (Caruso & Strand, 1999).

Kumin and Bahr (1999) reported that only thirty three percent of the children in their study demonstrated awareness of drooling revealing that most children showed hypo-responsiveness to tactile stimuli. They also reported that a lot of children rejected mixed food textures, tooth brushing, and face washing demonstrating hyper-responsiveness to touch. They avoided exploring objects with their mouths, thus depriving themselves of practice making movements with their lips, and tongue (Kumin, 1994). Oral hyposensitivity and hypersensitivity have also been reported in young children with Down syndrome (Frazier & Friedman, 1996). Characteristics of oral hyposensitivity included 'poor or no awareness of food on lips, slow registration of food in mouth, pocketing of food, and stuffing of mouth' (Frazier & Friedman, 1996). Children with Down syndrome are hence deprived of a lot of sensory stimulation that is imperative to appropriate motor development. From a motor learning perspective, these early movements experienced during oral exploration are vital to the acquisition of motor speech skills (Kumin & Adams, 2000). Since children with Down syndrome appear to experience difficulty with motor planning, it is important to describe the patterns they exhibit, and determine whether these patterns are characteristic of the symptom cluster labeled childhood apraxia of speech (Kumin & Adams, 2000).

There is very little evidence in literature regarding the presence of CAS in Down syndrome and no standardized tools exist to assess oral motor, oral praxis and verbal praxis skills in Kannada. The purpose of this study was to develop a protocol and examine oral motor, oral praxis and verbal praxis skills in Kannada speaking persons with Down syndrome and investigate whether CAS was present in this population. A protocol was developed to perceptually evaluate the oral motor, oral praxis and verbal praxis skills. This would form a preliminary basis for further research involving the use of more objective techniques such as acoustic analysis.

METHOD

Features suggesting poor oral and verbal praxis abilities in individuals with Down syndrome are reported by a few investigators (Dodd, 1976; Stoel-Gammon, 1981; Miller, 1987). Childhood Apraxia of Speech (CAS) is reported to be present in persons with Down syndrome. This study aims to investigate the oral motor, oral praxis and verbal praxis skills in persons with Down syndrome in order to understand the deficits if any, in these skills and to observe for their contribution to speech deficits in persons with Down syndrome. A 'standard groups comparison' design was used; the group with Down syndrome was compared with mental age matched persons with mental retardation (without Down syndrome) and typically developing children.

Aims of the study:

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

2) To carry out a pilot study and administer the protocol on a fraction of the participant groups to check for the appropriateness of scoring and instructions of the protocol.

3) To compare four groups of subjects for oral motor, oral praxis and verbal praxis skills- (a) Experimental group: persons with Down syndrome (b) Control group I: mental age matched persons with mental retardation (without DS) (c) Control

group II: chronological age matched typically developing children (d) Control group III: mental age matched typically developing children.

Participants

Thirty persons with Down syndrome (DS), thirty with mental retardation (without DS), and thirty typically developing children were included as participants in the study. All children were native speakers of Kannada. The two groups with disorders had mild to moderate mental retardation and were selected from fifteen special schools with Kannada as the medium of instruction. The typically developing children were selected from three mainstream schools with their medium of instruction and language used at home being Kannada. The numbers of persons in each group were determined by using a formula for calculation of sample size (Machin, Campbell, Fayers, & Pinol, 1997) using means and standard deviations from the pilot study. The formula used was:

$$m = \frac{2 \times [z_{(1-\alpha/2)} + z_{(1-\beta)}]^2}{\Delta^2}$$

Where m is the sample size,

$z_{(1-\alpha)}$ is a constant value of 3.2905 at 0.1% significance level,

$z_{(1-\beta)}$ is a constant value of 1.6449 at 95% of power, and

A is the standardized difference i.e. the difference between the means divided by the standard deviation. Means of 90 and 72 with standard deviation of 10 was considered from the isolated oral praxis assessment section of the pilot study. Hence A was found to be 1.8.

Using the formula, m was found to be 15.03, so a rounded number of 15 may be considered as sample size. However, a larger sample was included in the groups with disorders. In the experimental group and control group I, i.e. persons with Down syndrome and mental retardation (without DS), 30 participants each were included. In control group II i.e. chronological age matched typically developing children, 15 participants were included.

Experimental Group

Thirty children with Down syndrome including 15 males and 15 females between the ages 11 ;6 to 14;6 years with mild to moderate mental retardation were included in the experimental group. The chromosomal aberration in all persons with Down syndrome was trisomy 21. All persons in the experimental group had a mean length of utterance of at least three words. Persons with history of middle ear infections, visual impairments, and co-morbid problems such as autism, cerebral palsy, seizures, other developmental disabilities and severe behavioral problems were excluded. The children who were suspected to have hearing loss based on behavioral screening procedures during the investigation were also excluded from the study. Each child underwent a non-verbal psychological testing and based on the psychologist's report, participants with mild to moderate mental retardation were selected. The average chronological age of this group was 13;3 years; the average mental age was 5;0 years and the average intelligence quotient (IQ) was around 45. Details regarding their chronological ages, IQs, degrees of mental retardation and mental ages are provided in Table 1.

Table 1: Demographic details of participants with Down syndrome

SNo.	Chronological Age	Gender	Intelligence Quotient	Degree of retardation	Mental Age
1	13;2	Female	50	Moderate	6;6
2	12;0	Female	40	Moderate	4;8
3	14;3	Female	46	Moderate	6;5
4	14;0	Female	57	Mild	7;9
5	14;6	Female	48	Moderate	6;9
6	14;0	Female	49	Moderate	6;8
7	ll;10	Female	40	Moderate	4;5
8	13;0	Female	**57**	Mild	7;4
9	14;3	Female	38	Moderate	5;4
10	11;6	Female	40	Moderate	4;6
11	12;6	Female	45	Moderate	5;6
12	11;8	Female	35	Moderate	4;1
13	14;6	Female	35	Moderate	5;0
14	14;0	Female	57	Mild	7;9
15	14;0	Female	60	Mild	5;6
16	14;3	Male	44	Moderate	6;2
17	ll;10	Male	51	Mild	5;6
18	13;0	Male	35	Mild	4;5
19	14;0	Male	42	Moderate	5;8
20	13;1	Male	43	Moderate	5;6
21	14;3	Male	40	Moderate	5;7
22	14;6	Male	38	Moderate	5;5
23	13;5	Male	55	Mild	7;5
24	14;6	Male	43	Moderate	6;2
25	14;7	Male	38	Moderate	5;5
26	11;6	Male	41	Moderate	5;0
27	13;7	Male	40	Moderate	5;4
28	14;7	Male	40	Moderate	5;3
29	11;6	Male	64	Mild	7;3
30	12;0	Male	58	Mild	6;9

Control Groups

Two control groups were included in this study. One group having mental retardation without Down syndrome was included in order to check for the influence of mental retardation as a cause for speech problems. This was done in order to have mental retardation as a common factor with individuals of the experimental group. Another group included typically developing children in order to establish normative data for the perceptual assessment protocol that was developed.

Control Group I

This group comprised thirty children with mental retardation without Down syndrome (caused due to a non-syndromic and non-degenerative cause). The group included 12 females and 18 males, who were matched for mental and chronological age with the participants in the experimental group. All persons in this group were native speakers of Kannada, with the inclusion and exclusion criteria being the same as those of the experimental group except for the absence of Down syndrome. None of the children were suspected to have hearing loss. Each child underwent a non-verbal psychological testing and based on the psychologist's report, participants with mild to moderate mental retardation were selected. The average chronological age was 13;8 years, the average mental age was 5;7 years and the average IQ was around 47.

Table 2: Demographic details of participants with Mental retardation (without DS)

SNo.	Chronological Age	Gender	Intelligence Quotient	Degree of retardation	Mental Age
1	13;2	Female	45	Moderate	5;9
2	13;4	Female	41	Moderate	5;4
3	14;0	Female	40	Moderate	5;6
4	12;8	Female	61	Mild	7;8
5	14;4	Female	50	Moderate	7;2
6	11;7	Female	38	Moderate	4;3
7	14;6	Female	32	Moderate	4;6
8	14;7	Female	55	Mild	7;9
9	14;8	Female	48	Moderate	6;9
10	11;6	Female	65	Mild	7;4
11	14;0	Female	42	Moderate	6;0
12	11;8	Female	65	Mild	7;2
13	13;8	Male	45	Moderate	6;2
14	12;0	Male	50	Moderate	6;0
15	12;6	Male	45	Moderate	6;2
16	13;6	Male	50	Moderate	6;8
17	11;5	Male	36	Moderate	4;1
18	14;0	Male	46	Moderate	6;5
19	11;7	Male	63	Mild	**7;2**
20	14;1	Male	37	Moderate	5;3
21	14.7	Male	55	Mild	7;9
22	13.3	Male	40	Moderate	5;3
23	14.2	Male	49	Moderate	6;9
24	12.9	Male	50	Mild	6;5
25	14.1	Male	50	Moderate	7;0
26	13.8	Male	51	Moderate	5;6
27	14;0	Male	**58**	Moderate	**6;4**
28	14;2	Male	39	Moderate	5;6
29	14;8	Male	48	Moderate	7;1
30	ll;10	Male	36	Moderate	4;0

Control Group II

This group comprised fifteen chronological age matched typically developing children. They were in the age range of 11;6 to 14;6 years with a mean age of 13 years.

All children were selected based on a screening procedure that was carried out to identify children with communication disorders. The screening was done as part of routine clinical activities that involved administration of an 'identification checklist' (as depicted in Appendix 2) that assessed each child's articulation, fluency, and language skills. Only children who passed this screening test were included in the study.

Table 3: Demographic details of chronological age matched typically developing children.

SNo.	Chronological age	Gender
1	13;2	Female
2	12;0	Female
3	14;3	Female
4	14;0	Female
5	13;6	Female
6	14;0	Female
7	11;10	Female
8	13;0	Male
9	14;3	Male
10	11;6	Male
11	12;6	Male
12	11;8	Male
13	14;6	Male
14	11;6	Male
15	12;0	Male

Development of protocol

No standardized assessment protocol is available in Kannada to assess oral motor, oral praxis and verbal praxis skills. Hence a protocol called 'Assessment of oral motor, oral praxis and verbal praxis skills' was compiled and developed drawing support from various sources in the literature. The items were specifically designed to meet the needs of Kannada speaking individuals in the age range of 4 to 7 years (i.e. the mental age of individuals targeted in the experimental and control group I). The protocol includes mostly rating scales that are different for each task. The rating scales were task oriented and were not the same across different tasks because the tasks were not comparable. The details of the protocol are presented in Appendix 1. It consisted of the following sections:

I. Oral motor assessment protocol
    A. Posture
    B. Oral structures at rest
    C. Function of the oral mechanism for speech
    D. Oral sensory behavior
II. Oral praxis assessment protocol
    A. Isolated oral movements
    B. Sequential oral movements
III. Verbal praxis assessment protocol
    A. Isolated verbal movements
    B. Sequential verbal movements
    C. Assessment of diadochokinetic (DDK) tasks
    D. Word level praxis assessment
    E. Sentence level praxis assessment
    F. Analysis of spontaneous speech

Description of the assessment protocol

/. *Oral motor assessment protocol*

Individuals with Down syndrome are reported to present oral motor issues such as, small oral cavity (Sommers et al., 1988; Miller & Leddy, 1998; Stoel-Gammon, 2001), a short and narrow (Sommers et al., 1988) or high vault type hard palate (Stoel-Gammon, 1997). They are also reported to demonstrate Angle's class III malocclusions (i.e. lower teeth are anterior to the upper teeth) with prognathism (i.e. protruded lower jaw) (Sommers et al., 1988; Borea et al., 1990; Desai, 1997). Other investigators have noted tongue protrusion (Sommers et al., 1988; Kavanagh, 1995; Nowak, 1995; Stoel-Gammon, 2001), an open mouth posture (Rynders & Horrobin, 1996) and hypotonia or low muscle tone (Share & French, 1993; Miller & Leddy, 1998; Kumin & Bahr, 1999; Dykens et al., 2000).

In the present protocol, only oral structural issues that have a bearing on speech production were included. The first two sections A (posture) and B (oral structures at rest) were adapted from 'The battery of oral-motor behavior in children' (Long, Bahr, & Kumin, 1998) with the authors' permission. Most items from the protocol by Long et al. (1998) were included but the presentation was slightly changed. In the protocol by Long et al. (1998), the numbers of choices per item ranged from two to four and the scoring procedure was non-uniform. This was changed to two choices per item for assessment of posture and three choices per item for assessment of oral structures at rest. The participants were not required to carry out any movements on imitation or on command except for the assessment of trunk and neck movements that were included in posture assessment.

Table 4: Details regarding oral motor assessment protocol

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

Velleman (2003) emphasizes the need for assessing function of the oral mechanism for speech in terms of oral-nasal distinction, air build up for stops, and fricatives; and range of movement of articulators in persons with CAS. These assessments were carried out on observation of the participants during verbal tasks and participants were not required to perform any specific task on command.

Section D included assessment of oral sensory behaviour in persons with Down syndrome. Oral hyposensitivity and hypersensitivity have been reported in young children with Down syndrome (Frazier & Friedman, 1996). Characteristics of oral hypersensitivity reported in literature included 'rejection of age-appropriate food textures; reduced acceptance of food tastes, temperatures or smells; picky eaters; aversive or exaggerated response to touch in or around the mouth; hyperactive gag response; aversion to brushing teeth; and lack of age-appropriate mouthing of toys/hands'. Frazier and Friedman (1996) reported characteristics of oral hyposensitivity including 'poor or no awareness of food on lips, slow registration of food in mouth, pocketing of food, and stuffing of mouth'. In order to assess the oral sensory behaviour of participants in the study, a questionnaire for parents was developed including items from Abrash (2000) (see section D of Appendix 1). All statements in the questionnaire were made as simple as possible to make it easy for the parents to understand. They were also translated into Kannada by consulting a linguist and the questions asked to the parents were in Kannada. Before administration of the questionnaire, the purpose of the study, meaning of questions and scoring were explained to the parents and if they had any queries, they were encouraged to ask the investigator.

Scoring and/or analysis

Posture and oral structures at rest were analyzed by observing the participants during rapport building and while rest of the assessment was being carried out. Trunk and neck movements however were analyzed by asking them to perform the movements as depicted in Appendix 1. The scoring of these two sections was adapted from Long et al. (1998) test battery. A two-point rating scale was used for assessment of posture and a three-point rating scale was used for assessment of oral structures at rest. The scoring of observed behaviours was done by the investigator. Function of oral structures during speech was rated by observing the speech of children. It was assessed using a two-point rating scale for which observations were made during the verbal praxis assessment.

Oral sensory assessment was done by asking the parent(s) to fill a questionnaire. A four-point rating scale was used (never-0, occasionally-1, frequently-2 and always-3) to score the questionnaire for oral sensory assessment. All items were rated by the investigator based on parental input and observation of participants by the investigator during assessment. It may be noted that assessment of posture and oral sensory assessment were included in the pilot study and not in the final assessment.

//. ***Oral praxis assessment protocol***

Oral praxis deficits have been observed in persons with Down syndrome (Ferry et al., 1975; Elliott et al., 1990; Kumin & Adams, 2000). In order to assess oral praxis skills in these children, an oral praxis protocol was compiled based on the items proposed in the scales by Blakeley (1980) and Velleman (2003). Only isolated oral movement tasks were included from both these sources.

Table 5: Details regarding the oral praxis assessment protocol.

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

A. Isolated oral movements

These tasks were divided into those involving predominantly jaw, lip, and tongue movements. Tasks that did not fall into any of those categories such as puffing up of cheeks and clearing of throat were included under the category 'others'. As depicted in table 5, a total of nineteen tasks were divided into those predominantly involving jaw, lip, tongue and other movements. Participants were instructed to imitate all movements one after the other as demonstrated by the investigator. The investigator also used a carrier phrase 'Do this' before demonstrating each movement. The task was repeated once again or a second time, if the participant performed it inappropriately in terms of rate or accuracy or did not imitate it at all.

Scoring and / or analysis

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

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

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

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

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

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

B. Sequential oral movements

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

Scoring and / or analysis

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

Motor control score (MCS):

'2'- Both movements are precise in every parameter

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

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

Sequence maintenance score (SMS):

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

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

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

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

///. Verbal praxis assessment protocol

Verbal praxis deficits have been reported in persons with Down syndrome (Ferry et al., 1975; Hamilton, 1993; Kumin & Adams, 2000; Kumin, 2003). Verbal praxis skills in the participants of this study were evaluated in a protocol developed based on a task hierarchy of simple to complex verbal tasks. The details are depicted in table 6.

Table 6: Details regarding verbal praxis assessment protocol

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

A. Isolated verbal movements

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

Scoring and/or analysis

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

'3'- Movement/action is accurate

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

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

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

B. Sequential verbal movements

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

Scoring and/or analysis

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

Motor control score (MCS):

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

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

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

Sequence maintenance score (SMS):

'2'- Repeats all phonemes correctly

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

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

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

C. Assessment of diadochokinetic (DDK) tasks

Most assessment protocols developed for persons with CAS assess diadochokinetic tasks. DDK tasks were assessed by asking the participants to repeat syllables /pə/, /ʈə/, /kə/ (Alternate Motion Rates-AMR) and /pəʈəkə/ (SMR-Sequential Motion Rates) as fast as they could. If they did not understand the instructions, they were given cues by tapping a finger with every syllable and progressively moving it upwards. Analysis of the responses was done in terms of rate, numbers of attempts, accuracy and consistency.

Scoring and/ or analysis of numbers of attempts and rate

A maximum of five attempts were allowed for each child. The attempts taken by each participant were tabulated for AMR and SMR tasks. The total scores per task, per child were calculated and numbers of attempts were noted. The best attempt with at least ten iterations was considered for calculation of rate. Continuously uttered and clearly enunciated segments of iterations were marked using a software called 'Wavesurfer', an open source tool for sound visualization and manipulation (Sjölander & Beskow, 2005). The time taken for ten iterations was analyzed using the software and iterations per second were then derived using the formula:

$$DDK\ Rate = \frac{10}{\text{Time taken in seconds for ten iterations}}$$

Scoring and/ or analysis of accuracy

Accuracy is considered an important measure for analysis of DDK tasks in 3 to 4 year old typically developing children (Williams & Stackhouse, 2000). Responses from all participants were noted and were rated for accuracy in terms of articulation. If the first five repetitions were accurately produced, a score of '1' was given and '0' if the repetitions were inaccurate. The accuracy was also analyzed in terms nonsystematic articulation errors such as placement, voicing, perseveratory, deletion, insertion and exchange errors as defined by Yaruss and Logan (2001) as follows:

- Insertion error: an extra segment or syllable is inserted. Repetitions of speech disfluencies were not counted as insertion errors.
- Deletion error: a segment or syllable is deleted.
- Voicing error: a voiced segment is produced instead of a voiceless segment.
- Placement error: a segment is produced with an incorrect place of articulation. This can overlap with other errors, such as exchange or perseveration errors.
- Exchange error: two syllables within the same iteration are exchanged. Note that the syllables do not have to be adjacent.
- Perseveration error: a syllable is produced, then repeated (instead of the appropriate following syllable).

Scoring and /or analysis of consistency

Consistency from one repetition of pə-ʈə-kə to the next or token-to-token variability in the SMR tasks is important to evaluate praxis breakdown. Inconsistent errors characterize the speech of persons with CAS (Robin, 1992; Davis et al., 1998; Forrest & Morrisette, 1999; Nijland et al., 2002; Forrest, 2003; Nijland et al., 2003) and there are also a few reports of inconsistent speech errors in persons with Down syndrome (Dodd, 1976). In order to evaluate consistency in the DDK tasks, the following scoring procedure was used:

'3'- Consistent repetitions; no change from one repetition to the next

'2'- Three of four repetitions are consistently repeated

' 1'- Two of four repetitions are consistently repeated

'0'- All repetitions are different from one another.

D. Word level praxis assessment

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

'0'-1 don't know this word

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

'2'-1 know this word well

Thirty most familiar words i.e. the ones that were rated as '2' were selected from this list including five words each from disyllabic, trisyllabic and multisyllabic words with and without clusters. In order to include more complex words, another list of hundred words with two and three clusters was prepared from a Kannada dictionary. These words were short-listed to thirty words by a speech language pathologist and then ten words by another speech-language pathologist. The list was finalized after consulting a linguist regarding the dialectal appropriateness of the words amongst Kannada speaking persons of Bangalore and Mysore. All words were arranged in a hierarchy of increasing length and presence of clusters as follows:

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

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

Scoring and / or analysis

The investigator uttered the list of forty words one by one and the participants were asked to imitate them. The analyses were carried out in three ways:

a) Analysis of phonological process errors:

All words were transcribed using the broad system of International Phonetic Alphabet (IPA) and total numbers of words produced correctly were tabulated. Definitions of phonological processes described by Stoel-Gammon and Dunn (1985), Lowe (1994, 1996), Velleman (1998) and Pena-brooks and Hegde (2000) were used. Certain other phonological processes that are not traditionally described in literature were defined operationally and included in the analyses. The phonological processes were further classified into space, timing and whole-word errors (Velleman, 2003) that describe phonological errors in persons with CAS instead of the traditional classification of syllable structure, and syllable substitution processes as follows:

- Space errors: fronting, backing, palatalization, depalatalization, and vowel deviations including vowel prolongation, vowel centralization, monophthongization etc.

- Timing errors: voicing errors, affrication, deaffrication, denasalization etc.
- Whole word errors: cluster reduction, reduplication, consonant harmony, migration, metathesis, epenthesis, consonant deletions, syllable deletions.

b) Sequence maintenance score:

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

Sequence maintenance score (SMS) in disyllabic words

'2'- Repeats both syllables in the correct order.

'1'- Repeats both syllables in reverse order or repeats a syllable or adds/deletes a syllable.

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

SMS in trisyllabic and multisyllabic words

'2'- Repeats all syllables in the correct sequence.

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

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

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

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

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

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

Scoring and /or analysis

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

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

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

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

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

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

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

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

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

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

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

b) Sequence maintenance score:

This score was adapted from the scoring of 'Oromotor production in word sequences and sentences' section of VMPAC (Hayden & Square, 1999). However, VMPAC does not use greater than four-word sentences, and the protocol used in the study used as many as six words. So the scoring was divided into two, i.e. for lesser than and for greater than 3 words. A three point rating scale was provided as follows:

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

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

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

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

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

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

b) Sentence length:

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

F. Analysis of spontaneous speech

A spontaneous speech sample of at least hundred utterances was collected from each child by indulging in general conversation about home, routine, and school. Age appropriate (Venkatesan, 2003) toys and pictures were also used in order to obtain the sample that was then transcribed for subsequent analysis.

Scoring and/ or analysis

The recorded sample was transcribed using the broad system of IPA transcription with a few diacritic markers. The analyses were carried out in two ways. PCC and PVC scores as described under the section of sentence level praxis assessment were calculated and phonotactic analyses were also done. Phonotactics refers to the way in which syllables behave in utterances and hence reflect on errors that affect an entire syllable or word.

Several researchers have hypothesized that the underlying deficit in CAS is in the syllabic framework (Davis et al., 1998; Marquardt et al., 2002; Maassen, 2002; Nijland et al., 2003). Other researchers have postulated sequencing as the primary deficit (Thoonen et al., 1996). Davis et al. (1998) proposed 8 key characteristics of CAS including frequent omissions, increased errors on longer units, and predominant use of simple syllable shapes. Lewis et al. (2004) found that children with CAS who were followed from preschool into school age differed from children with speech disorders at school age having more syllable sequencing errors in conversational speech than the speech-delayed children. Thoonen et al. (1996) also noted that multisyllabic word tasks were critical for differentiating CAS from dysarthria.

Kumin and Adams (2000) report the presence of phonological errors suggestive of deficits in the syllabic framework amongst children with Down syndrome, specifically those indicative of CAS. Those include increased omissions, decreased intelligibility on longer units (that indicates difficulty at the structural level rather than the segmental level), and also perseverative and anticipatory errors. Hence, a phonotactic analysis of the speech of persons with Down syndrome is essential for examining their ability to organize speech sounds in long utterances, such as words and sentences.

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

$$\frac{\text{Number ofCVsyllables}}{\text{Total number o/syllables}} \times 100 = \%\ \text{CVsyllables}$$

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

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

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

Test procedure

An informed consent from the parent or caregiver of each participant was taken before administration of the test. All participants were tested individually in fairly quiet and familiar surroundings. The audio-video recordings were done using a Panasonic digital camcorder NV GS-15. These recordings were supplemented with audio recordings that were done using a digital voice recorder VY-H350 with an external microphone placed approximately 10 cm from the mouth of the participant. Initially the investigator established rapport with the child by talking to the child in general and showing pictures taken of the child on the digital screen of the camera. The video camera was placed on a tripod stand in front of the child and the investigator was seated at a 45° azimuth from the child away from the view of the camera. The seating arrangement was such that the child was not distracted by the presence of the camera. Video recording was started whilst administration of the test battery where positive feedback and appropriate cues were given in order to elicit the speech. Each participant was also provided with intermittent breaks of approximately every 20 minutes or whenever required based on the temperament of the child. Total recording time ranged from 45 minutes to 1 hour per child depending on the severity of the speech disorder and the child's temperament.

The audio-video recordings from the cassette of the digital video camera were loaded on to a Personal Computer and recorded on to a Video Compact Disc (VCD) that were then analyzed. The videos were viewed on a 17 inches wide computer monitor and analyzed by using headphones. Each child's sample was analyzed separately and scores were given in the scoring sheet as provided in Appendix 1. Transcription was carried out using broad IPA transcription method along with a few diacritic markers. Scoring of most test items was done using a rating scale that was designed for each task separately. Those items in the protocol that had to be rated were given scores according to the instructions in the scoring sheet. Other analyses such as analyses of phonological processes, calculation of PCC, PVC and phonotactic analyses were carried out separately.

Pilot study

No standardized protocol is available in Kannada to evaluate oral and speech motor skills in persons with Down syndrome. Many of **the** items used in the protocol were adapted from different sources in the literature, but they were translated in Kannada and certain changes were made in the scoring. The pilot study was hence necessary in order to evaluate whether the assessment protocol was effective in terms of items included and the scoring method used. The developed assessment protocol was administered on 10% of the intended sample as a pilot study by the investigator. The following facts were verified by conducting the pilot study:

- Appropriateness of instructions.

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

The pilot study was conducted on seven children each in the experimental group (persons with Down syndrome), control group I (persons with mental retardation without DS) and control group II (chronological age matched typically developing children). Total scores were calculated based on the rating scale of the protocol and these were tabulated for statistical analysis. Based on the results of the pilot study, it was observed that instructions to the participants, scoring, quality of video recording, and sound levels were appropriate. No additional tasks or materials were required. One-way ANOVA was administered to evaluate whether significant differences existed across the three groups of participants.

Results from the pilot study revealed significant differences across the three groups for all sections of the assessment protocol except for the assessment of posture, and oral sensory skills. Moreover, some parents of the participants with Down syndrome reported that as younger children, they did exhibit some sensory problems, but outgrew these problems with age. None of the parents from the other two groups reported the same. Based on this and the fact that no significant differences were observed across the three groups, these two sections were removed from the protocol. A major change made in the study was the inclusion of mental-age matched typically developing children as control group III since the chronological age matched typically developing children scored almost 100% in all tasks. Details are provided in table 7.

Table 7: Demographic details of chronological age matched typically developing children.

SNo.	Chronological Age	Gender
1	4;1	Female
2	5;3	Female
3	4;5	Female
4	6;7	Female
5	6;10	Female
6	4;2	Female
7	5;7	Female
8	5;8	Male
9	6;2	Male
10	4;7	Male
11	4;1	Male
12	5;9	Male
13	5;11	Male
14	6;1	Male
15	6;0	Male

Fifteen typically developing children in the other group were in the age range of 4;1 to 6; 10 years matched for mental age with the children in the two groups with disorders. Average age of the children was 5;5 years. On phonological analysis of word level praxis assessment in the pilot study, certain phonological processes that are not traditionally described in literature were noticed. They were gemination, degemination, vowel decentralization, medial consonant deletion, and syllable deletions in initial, medial and final positions. These phonological processes were operationally defined.

Vowel errors such as, shortening, raising and lowering (Pollock, & Keiser, 1990; Pollock, 1994) were also noticed and included in the list of space, timing and whole word errors.

Reliability

Reliability measures were done in order to establish the reliability of the protocol, rating scales and that of IPA transcription. Three types of reliability measures were carried out for which two different judges (Judge 1, and 2) were involved. The judges were matched in age, gender, education, and work experience with the principal investigator. They were explained the purpose of the study and were given appropriate training and/or instructions to carry out the assessment.

1. Test-retest reliability: This was carried out on 10% of the data from each of the four groups of participants to test the reliability of scores when the assessment was carried out again. This recording was carried out within two weeks of the first testing. Analyses were carried out by the principal investigator in the same way as described in the analysis of the assessment protocol. The scores obtained were subjected to statistical analysis. Reliability coefficient alpha was calculated and was found to be 0.8 that showed high reliability between the first and second tests.

2. Inter- and intra-judge reliability: Rating scales adapted in the protocol are subjective forms of assessment that are judgment based and hence susceptible to great variability. In order to establish reliability of judgments that involved rating scales, inter- and intra-judge reliability of scoring were carried out. Judge 1 was trained to

rate different items in the assessment protocol, and also given a practice trial. 10% of the data from each of the four groups of participants were analyzed by both principal investigator and judge 1 together and scores were tabulated for statistical analyses. Reliability coefficient alpha was calculated and the average for all subjects was found to be 0.78 that showed high reliability between the first and second judgments. lntra-judge reliability coefficient was found for 10% of the data. Reliability coefficient alpha was 0.85 that also showed high reliability.

3. Transcription reliability: Inter- and intra-judge reliability measures were carried out to determine reliability of IPA transcription. 10% of the speech samples from each of the four groups of participants were subjected to reliability scoring. Judge 2 was given a brief overview of the different symbols used in IPA. Segment to segment reliability of samples revealed an inter-judge reliability of 79.02%. Intra-judge reliability was carried out by transcribing 10% of the data from all four groups within two weeks of the first transcription. It was found to be 82.89%.

Inter- and intra-judge reliability measures were also carried out to judge the disfiuency, and groping errors of the participants by judge 2 and the principal investigator respectively. Segment to segment inter-transcriber reliability was 75.6% for disfiuency and groping errors. Intra-transcriber reliability was carried out within two weeks of the first transcription and it was found to be 80% for these errors.

Oral motor, oral praxis and verbal praxis skills of persons with Down syndrome were compared with mental age matched persons with mental retardation and typically developing children. An assessment protocol was prepared to assess these three skills and analyses were carried out to evaluate each of the different items included in the protocol. The different analyses included the use of rating scales, calculation of PCC and PVC; phonological process and phonotactic analyses. The scores were tabulated for each participant and results obtained were subjected to statistical analyses.

RESULTS AND DISCUSSION

The study aimed to analyze the oral motor, oral praxis, and verbal praxis skills in persons with Down syndrome in the age range of 11 ;6 to 14;6 years and compare their performance with mental and chronological age matched persons with mental retardation (without Down syndrome) and typically developing children. A protocol was developed to assess the selected skills following which a pilot study was conducted to evaluate the effectiveness of the items and the scoring method used in the protocol. Based on the outcome of the pilot study, modifications were incorporated in the protocol before its administration on the participants. Statistical analyses were carried out using software called SPSS (Statistical package for Social Sciences) - version 14 to compare the performance of the groups for oral motor, oral praxis and verbal praxis skills.

In order check for the presence of gender effect within each parameter, Mann-Whitney U test was carried out for the sections of assessment that used a rating scale and Independent t-test was carried out for those involving numerical values. These analyses revealed that no significant differences in the performance on various items were present between male and female participants of the study. Hence, in the final analysis, data was combined to compare the different groups of participants i.e. persons with Down syndrome (DS) as the experimental group; persons with mental retardation (without DS) as control group I, chronological age matched typically developing children (control group II) and mental age matched typically developing children (control group III).

The pilot study included only control group II (i.e. chronological age-matched typically developing children). Since the performance score of this group was 100% in all tasks, fifteen mental age matched typically developing children ranging in age from 4;1 to 6; 10 years were also included. Both groups of typically developing children were included in the final analysis as control group Ill-mental age (MA) matched typically developing children and control group H-chronological age (CA) matched typically developing children. Since rating scales were used in the protocol, Kruskal-Wallis, a non-parametric test was used to find out whether there were any significant differences between the groups. Since significant differences were present, pair-wise analysis was done using Mann-Whitney test that showed the same results as the one-way ANOVA. Hence, one-way ANOVA has been used in order to find the main effect of groups. When significant results were found, Duncan's post-hoc test was done. Friedman test was carried out for within group analysis in isolated oral and verbal praxis skills to compare percentage scores. If significant results were found, it was followed by Wilcoxon signed rank test. Uncorrelated equality of proportions was carried out to compare the frequencies of persons exhibiting the various phonological processes in the three groups. The results are presented under the following sections.

I. Oral motor skills

A. Oral structures at rest

B. Function of oral mechanism for speech

II. Oral praxis skills

A. Isolated oral movements

B. Sequential oral movements

III. Verbal praxis skills

A. Isolated verbal movements

B. Sequential verbal movements

C. Assessment of diadochokinetic tasks

D. Word level praxis assessment

E. Sentence level praxis assessment

F. Assessment of spontaneous speech

I. Oral Motor Skills

Persons with Down syndrome are reported to have various oral deficits and in order to assess them, an oral motor assessment was carried out using the protocol as given in Appendix 1. The following sections were included:

A. Oral structures at rest

B. Function of the oral mechanism for speech

A. Oral structures at rest

Oral structures of all participants were assessed for (a) placement of jaws, lips, tongue at rest, (b) presence of hypotonia, and (c) other behaviours such as drooling, and involuntary movements. A three point rating scale from 0 to 2 (where 2 indicated better scores) was used to assess each of these items and the raw scores were tabulated. One-way ANOVA was carried out on the raw scores in order to compare the performance across the four groups. A significant main effect of groups was found. The raw scores are shown in table 8, and figure 1. Duncan's post-hoc test revealed a significant difference at .001 levels of significance between the means of experimental and control groups. No significant mean differences were observed between the three control groups. In other words, the skills assessed for oral structures at rest were similar in the control groups.

Table 8: Means, SDs and one-way ANOVA for assessment of oral structures at rest.

Oral motor assessment	Down syndrome (DS)		Mental retardation (without DS)		Typically developing Children (MA matched)		Typically developing Children (CA matched)		One-way ANOVA
	Mean	S.D	Mean	S.D	Mean	S.D.	Mean	S.D.	F(2,72)
Oral structures at rest	13.66	1.84	15.83	0.37	16.00	0.00	16.00	0.00	29.038***

*** p< .001

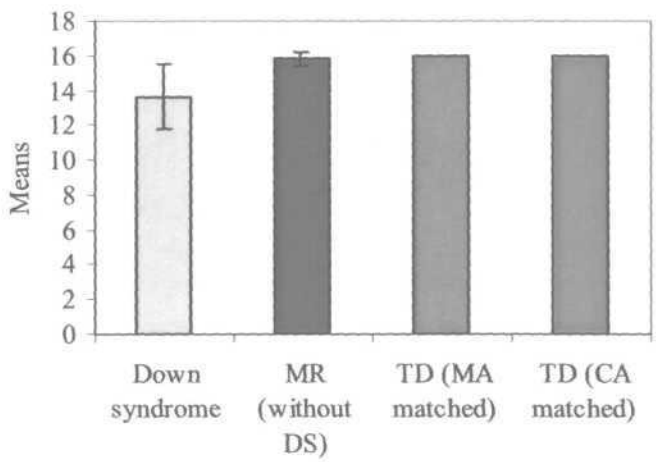

Figure 1: Means, and SDs for assessment of oral structures at rest.

Persons with Down syndrome had significantly greater deficits in the oral structures at rest than the control groups. Their raw scores ranged from 10 to 16. The raw scores of persons with mental retardation (without DS) ranged from 15 to 16 and the typically developing children obtained full scores. The scores on each item of the section on oral structures assessment at rest are shown in table 9 and figure 2.

Table 9: Means, and SD for oral structures at rest.

S.No	Oral structures at rest	Down syndrome (DS)		Mental retardation (without DS)		Typically developing Children (MA matched)		Typically developing Children (CA matched)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	Jaw alignment	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
2	Jaw position	1.00	0.78	1.83	0.37	2.00	0.00	2.00	0.00
3	Position of lips	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
4	Presence of drooling	1.96	0.18	2.00	0.00	2.00	0.00	2.00	0.00
5	Tongue placement	1.46	0.57	2.00	0.00	2.00	0.00	2.00	0.00
6	Tone	1.30	0.70	2.00	0.00	2.00	0.00	2.00	0.00
7	Involuntary movements	1.96	0.18	2.00	0.00	2.00	0.00	2.00	0.00
8	Concomitant movements of other body parts	1.93	0.25	2.00	0.00	2.00	0.00	2.00	0.00

From table 9, it is evident that none of the children exhibited jaw and lip protraction or retraction problems. Amongst all items, persons with Down syndrome achieved the least scores in positioning of the jaw. Around 30% of persons with Down syndrome exhibited slight opening of the jaw and another 30% exhibited noticeable opening of the jaw. The group with DS also obtained poor scores in placement of tongue in the mouth indicating the presence of hypotonia of the tongue in around 50% of individuals. Around 20% of these individuals also exhibited tongue thrust. Open jaw was also observed, indicating hypotonia in the jaw as well. Hence, hypotonia of tongue and jaw was observed in more than 50% of the individuals with Down syndrome indicated by position of tongue (placed outside) and jaw (in open position) at rest.

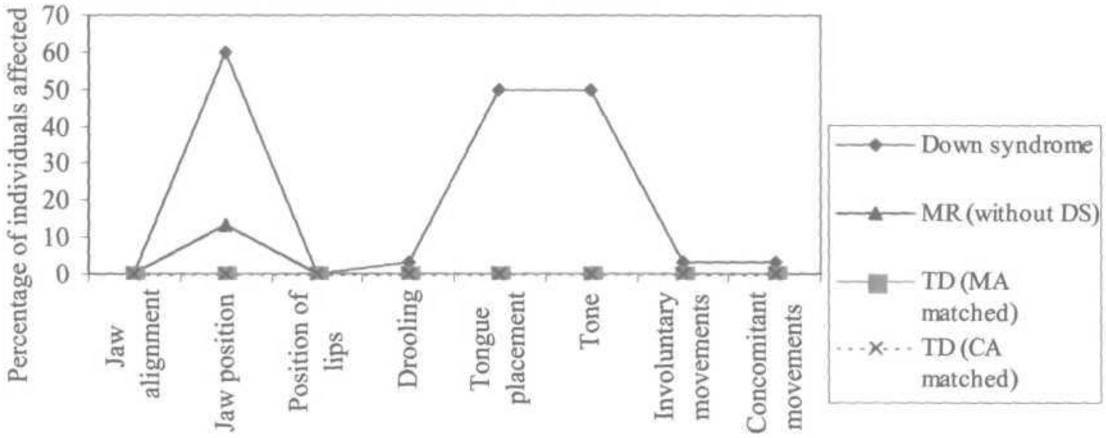

Figure 2: Percentage of individuals with deviant behaviours on oral structural assessment at rest.

Open mouth posture (Frazier & Friedman, 1996; Desai, 1997; Kumin & Bahr, 1999; Kumin et al, 2001), difficulty with jaw closure and subsequent lip closure (Kumin & Bahr, 1999; Bahr & Hillis, 2001), tongue thrust (Spender et ah, 1996; Desai, 1997; Kumin & Bahr, 1999; Bahr & Hillis, 2001; Kumin et ah, 2001), and hypotonia (Share & French, 1993; Kumin & Bahr, 1999) have been reported in Down syndrome. However the results need to be viewed in light of the differences in age ranges used in the reported studies. Kumin and Bahr (1999) reported open mouth posture in 71%, tongue thrust in 52% and hypotonia of lips and tongue in around 44% and 80% of the children. Share and

French (1993) reported a 95% occurrence of hypotonia in children with Down syndrome. Hypotonia is observed in around 50% of persons with Down syndrome in this study as well. Around 43% of persons with Down syndrome exhibited mild hypotonia and moderate hypotonia was noticed in 6.67%.

Assessment of oral structures at rest in typically developing children did not reveal any deviations on all items tested, whereas persons with mental retardation exhibited poor performance only in jaw position. Persons with mental retardation (without DS) obtained a mean raw score of 1.83 in the assessment of jaw position because a 'slightly' open jaw was observed in some children. This was due to the presence of protruding teeth in 10% of the individuals and malaligned and big teeth in 3.34%.

Drooling, involuntary movements and concomitant movement of oral structures with other parts of the body were observed in 3.34% of the individuals with DS. Children with Down syndrome are often reported to exhibit drooling (Desai, 1997; Kumin & Bahr, 1999; Morris & Klein, 2000). Kumin and Bahr (1999) reported drooling in 41% of the children with Down syndrome they studied. However, the age range included in their study was 8 months to 4; 11 years and not many reports of oral problems in older children are available. Sommers et al. (1988) did not observe drooling in persons with Down syndrome in the age range of 17-22 years included in their study. The control groups in this study did not exhibit drooling and involuntary movements.

Varying degrees of oral problems were noted in persons with Down syndrome. The control groups did not exhibit significant problems. The major deficit noticed in Down syndrome was open mouth posture (60%). This could be due to hypotonia of a mild degree that was observed in around 43% of the children. Other behaviours such as drooling, involuntary movements and presence of concomitant movements of oral structures with other parts of the body were less prevalent and were not so severe as to affect the production of speech significantly. Persons with Down syndrome in general demonstrated poor oral skills than the other two control groups and this observation supports previous literature in this area.

B. Function of the oral mechanism for speech

The function of oral mechanism for speech was rated based on the inferences drawn from the speech assessment of all participants. Observations included tests for adequacy of intra-oral breath pressure for stops, air build-up and precision of fricatives, oral-nasal distinction, and range of movement of lips, tongue and jaw. Raw scores were tabulated using a two-point rating scale from 0 to 1. These scores were then subjected to statistical analyses using one-way ANOVA. A significant main effect of groups was found. Since chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. The group mean performance is shown in table 10 and figure 3.

Table 10: Means, SD, and one-way ANOVA for function of oral mechanism for speech.

Oral motor assessment	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Function of the oral mechanism for speech	3.23	1.95	5.63	0.61	6.00	0.00	6.00	0.00	34.09***

*** p< .001

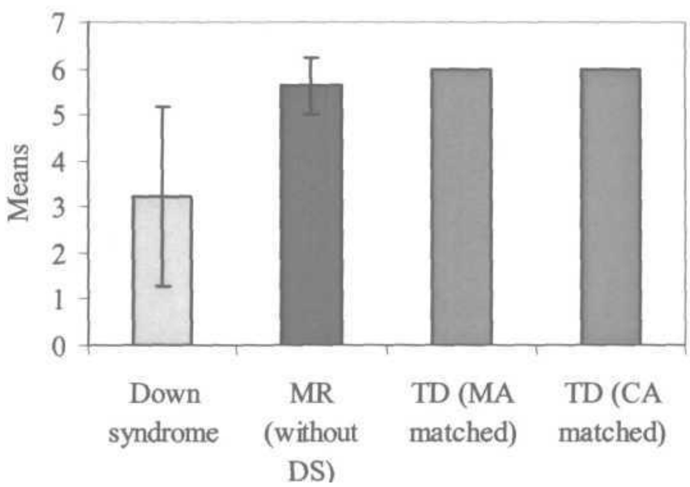

Figure 3: Means and SDs for function of oral mechanism for speech

Persons with Down syndrome as a group differed significantly from the control groups and their raw scores ranged from 0 to 6. Duncan's post-hoc test revealed that the control groups I (persons with mental retardation without DS) and III (mental age matched typically developing children) did not differ from each other significantly, but individual variations existed. Raw scores of persons with mental retardation (without DS) ranged from 4 to 6 and the typically developing children obtained complete scores. Table

11 and figure 4 show the mean scores of groups for individual function of the oral mechanism.

Table 11: Means, SDs for individual functions of oral mechanism for speech.

SNo	Function of oral mechanism for speech	Down syndrome (DS)		Mental retardation (without DS)		Typically developing Children (MA matched)		Typically developing Children (CA matched)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	Intra-oral breath pressure for stops	0.66	0.47	0.96	0.18	1.00	0.00	1.00	0.00
2	Air build up for fricatives	0.30	0.46	0.93	0.25	1.00	0.00	1.00	0.00
3	Oral-nasal distinction	0.46	0.50	0.83	0.37	1.00	0.00	1.00	0.00
4	Range of movement of lips	0.63	0.49	0.96	0.18	1.00	0.00	1.00	0.00
5	Range of movement of jaw	0.53	0.50	1.00	0.00	1.00	0.00	1.00	0.00
6	Range of movement of tongue	0.50	0.50	0.96	0.18	1.00	0.00	1.00	0.00

It is evident from table 11 that persons with Down syndrome obtained poorer scores in all test items when compared to the control groups. Air build up and precision for the production of fricatives was most affected in persons with Down syndrome followed by intraoral breath pressure for stops, and range of movement of tongue and jaw. Figure 4 depicts the percentage of individuals affected across all groups.

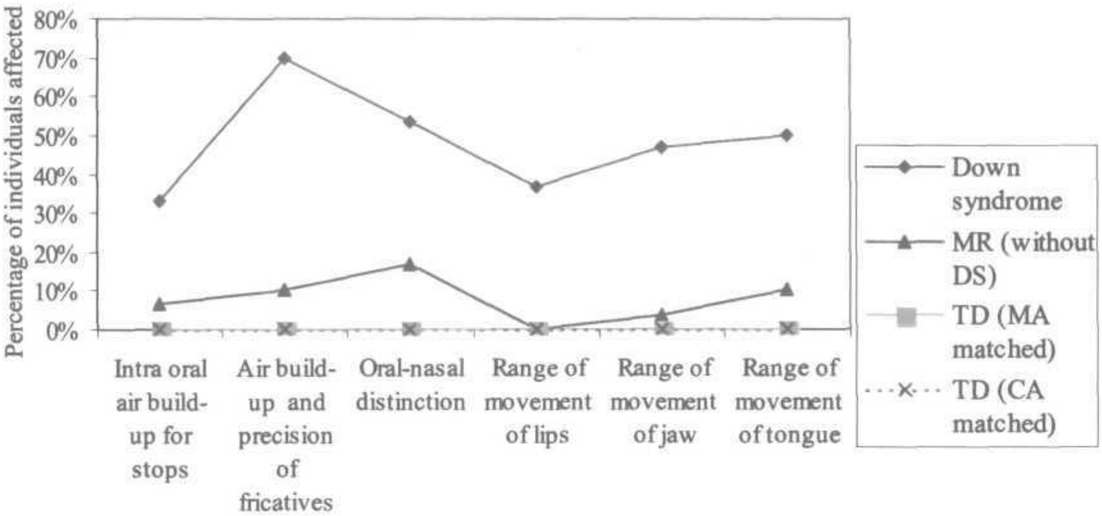

Figure 4: Percentage of persons affected in 'function of oral mechanism for speech' tasks across all groups of participants.

In persons with Down syndrome, precision of fricatives was affected the most i.e. around 70% of children were observed to have poor precision for production of fricatives. Fricatives require greater precision of articulators, are considered as difficult sounds to produce by persons with Down syndrome (Van Borsel, 1988) and are generally acquired late (Zisk & Bialer, 1976; Bleile & Schwarz, 1984). More motoric control is required for fricatives than for stops, and hence, stops were affected in around 33% of the group with Down syndrome. These results are supported by those of Kumin et al. (2001) who also reported of difficulties in intra-oral breath pressure.

Persons with Down syndrome also obtained poor scores for oral-nasal distinction when compared to the control groups as evident from table 11. Difficulties with oral-nasal distinction that reflect on the velopharyngeal competence were observed in 53.34% of individuals with Down syndrome. Difficulties with velopharyngeal closure have also been reported in the literature in around 25% of 17 to 22 year old individuals studied by Sommers et al. (1988). Table 11 also reveals that range of movement of tongue was the next most affected item followed by range of movement of the jaw. Figure 4 depicts the percentage of individuals with Down syndrome affected in the functions related to range of movement of lips, jaw and tongue in persons as 36.67%, 46.67%, and 30% respectively. This was probably due to the presence of hypotonia in the oral structures that in turn led to the limitation of oral movements (Bahr & Hillis, 2001).

In comparison, persons with mental retardation (without DS) exhibited major deficits in maintaining distinction between oral and nasal speech sounds, followed by precision of fricatives obtaining raw scores of 0.83 and 0.93 respectively for these two items. However, persons with mental retardation (without DS) did not differ significantly from control groups III and II i.e. mental age and chronological age matched typically developing children respectively. None of the participants in the control group I, i.e. persons with mental retardation (without DS) showed problems with range of movement of lips, 10% exhibited problems in range of tongue movement and one person i.e. 3.34% exhibited problems in range of movement of jaw. Five persons (16.67%) were observed to have difficulty in oral-nasal distinction, three persons (10%) with precision of fricatives and two persons (6.67%) with intra-oral build-up for stops. Both groups of typically developing children did not exhibit any such difficulties.

While the control groups were not affected much in terms of functions of oral structures at rest, different degrees of problems were observed in persons with Down syndrome. Function of the speech mechanism in terms of intra-oral breath pressure and velopharyngeal mechanism were affected most amongst the skills tested.

From the results of the section on oral motor assessment, it is evident that as a group, persons with Down syndrome have more oral motor issues in terms of structure as well as function. However, there are variations within the group and not all persons were affected equally in the different domains. It is a challenge to evaluate how much these oral motor issues affect oral and speech praxis and the following sections make a preliminary attempt to evaluate the same.

II. Oral Praxis Skills

Oral praxis skills were assessed in all groups of participants in two tasks: (a) isolated oral movements and (b) sequential oral movements. All observations were based on rating scales that constituted the raw scores. The raw scores were then subjected to statistical analyses using one-way ANOVA. Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups.

A. Isolated oral movements

In this task, all participants were instructed to imitate the oral movements as carried out by the investigator. The responses were rated on a scale of 5 from 0 to 4

(Appendix 1) depending on accuracy, and rate of the responses; and also the numbers of repetitions required to elicit the behaviour. The ratings of the behaviours were taken as raw scores that were subjected to statistical analysis using one-way ANOVA. The main effect of groups was significant. The results are shown in table 12 and figure 5. As is evident from table 12 and figure 5, the groups significantly differed from one another at .001 levels of significance. Raw scores of persons with Down syndrome ranged from 21 to 75, and those of persons with mental retardation (without DS) ranged from 48 to 76. Mental age matched typically developing children scored in the range of 70 to 76 and chronological age matched children obtained complete scores. Duncan's post-hoc test revealed that persons with Down syndrome exhibited significantly greater oral praxis problems in isolated oral movements than the other two groups. Control group I i.e. persons with mental retardation (without DS) differed significantly from control group III (MA matched typically developing children).

Table 12: Means, SDs and one-way ANOVA for isolated oral movements in oral praxis assessment.

Oral praxis assessment	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Isolated oral movements	52.26	14.40	67.03	7.12	73.93	2.05	76.00	0.00	27.26***

*** p< .001

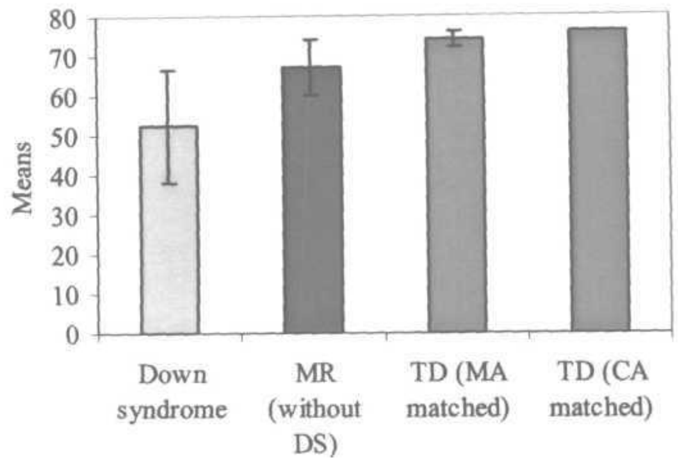

Figure 5: Means and SDs of isolated oral movements

Isolated oral movements were divided into predominantly lip, jaw, and tongue movements. Those movements that did not fall into any of these categories such as puffing of cheeks and clearing of throat were included in the 'others' category. Raw scores from these categories are given in Table 13.

Table 13: Means, and SDs of individual structures for isolated oral movements.

S.No.	Isolated oral movements	Down syndrome (DS)		Mental retardation (without DS)		Typically developing Children (MA matched)		Typically developing Children (CA matched)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	Jaw movements	11.70	3.17	13.90	1.63	15.80	0.41	16.00	0.00
2	Lip movements	14.70	4.40	17.70	2.15	19.40	1.24	20.00	0.00
3	Tongue movements	21.33	6.21	27.93	3.26	30.33	1.23	32.00	0.00
4	Others	4.40	2.81	7.46	1.13	7.60	0.82	8.00	0.00

Since the numbers of items in each of these categories namely, lip, jaw, tongue and others was not constant, the mean scores were converted to percentage scores in order to compare the performances between the categories within each group. Mean percentage scores were compared and are depicted in figure 6.

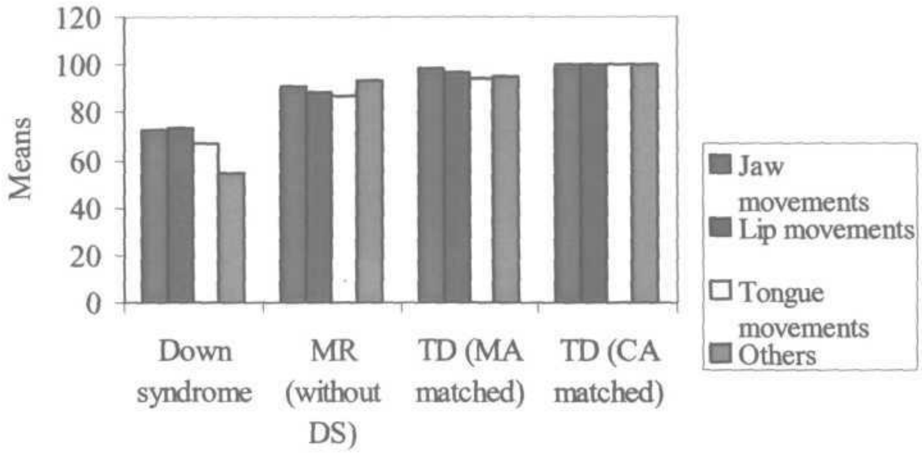

Figure 6: Percentage scores of isolated lip, jaw, tongue and other movements

Friedman test was used to find out whether there were significant differences between the categories within each group. Since percentages were compared instead of raw scores, Friedman test was used to carry out this analysis. Wilcoxon signed rank test was then used to find out which of the categories were significantly different from one another. This comparison was carried out only for the experimental group and control groups 1 and III i.e. persons with mental retardation (without DS) and mental age matched typically developing children. This was because the chronological age matched typically developing group i.e. control group II obtained 100% scores in all tasks.

Table 14: Friedman test depicting pair wise comparisons of lip, jaw, tongue and other movements within each participant group

S.No.	Isolated oral movements	Down syndrome (DS)	Mental retardation (without DS)	Typically developing Children (MA matched)
	Pairs	|z|	|z|	|z|
1	Jaw-lip movements	0.40	1.23	0.73
2	Lip-tongue movements	2.26*	0.75	1.65
3	Tongue-other movements	1.90*	2.34	0.55
4	Jaw-other movements	2.61**	1.03	1.38
5	Lip-other movements	3.37**	1.75	0.28
6	Jaw-tongue movements	1.97*	2.13*	2.70**

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

Table 13 depicts that persons with Down syndrome exhibited poorest performance for 'other' movements followed by tongue movements. The next most affected categories were the lip and jaw movements that were not significantly different from one another. However, no significant differences were observed between lip and jaw movements as is evident from table 14. Hence, in persons with Down syndrome, tongue and 'other' movements were more affected than lip and jaw movements. While tongue, jaw and lip movements involved predominant movements of the respective structures, 'other' movements involved co-ordination of many different structures. This could be the reason why these movements were more affected than movements of lip, jaw and tongue.

In control group I i.e. persons with mental retardation (without DS), tongue movements were most affected, followed by lip, jaw and 'other' movements. However, significant differences were observed only between tongue and 'other' movements, i.e. the most and the least affected categories. Mental age matched typically developing children (control group III) also had more errors in tongue movements followed by lip, 'other' and jaw movements. The only difference between control groups I and III was that scores for jaw movements were better than those for 'other' movements in control group I. Control group III also showed significant differences for the least and most affected groups i.e. tongue and jaw movements. Within group comparisons revealed that persons with Down syndrome obtained better scores for lip and jaw movements when compared to tongue and 'other' movements. On the other hand, the two control groups showed better scores for 'other' and jaw movements when compared to tongue and lip movements. Better scores were observed for tongue movements. The only significant differences observed were between tongue movements and the tasks that obtained least scores i.e. jaw movements for control group I and 'other' movements for control group III. Poorer scores for tongue-related tasks could be because more precision is required for tongue movements than movements related to jaw and lips. Tongue movements for speech are mastered later in life when compared to other movements (Kent, 1976). Jaw and lip movements were not significantly different for any of the groups probably because the lip and jaw move together and their movements are related.

Persons with Down syndrome had more oral praxis issues than the other two groups as observed from the results of isolated oral movement assessment of oral praxis. However, there was heterogeneity within the group. Out of 76, raw scores within the group with Down syndrome ranged from 21 to 75, indicating that some persons with Down syndrome performed the oral praxis movements better than the others. Elliott et al. (1990) reported that sixteen persons with Down syndrome in their study exhibited better scores on oral praxis tasks than mental and chronological age matched control groups of persons with 'undifferentiated' mental retardation. Kumin and Adams (2000) also reported high scores (100%) in volitional oral tasks with three of their seven participants with Down syndrome.

Another issue that needs to be noted is that even in persons with CAS without Down syndrome, conflicting reports about the presence of oral praxis problems exist. For example, while difficulties in performing non-speech oral movements were considered to characterize CAS (Hall, 2000), others did not indicate any relationship between CAS and oral-motor behaviors (Shriberg et al., 1997a, 1997b, 1997c; Davis et al., 1998). The group with mental retardation (without DS) also exhibited some amount of heterogeneity in scores. In this group, from a total of 76 the raw scores ranged from 48 to 76. This implies that some of them had poorer oral praxis skills than others within the group. But it is important to note that most children with mental retardation (without DS) were able to perform the movements, but with repetitions.

To summarize, the results obtained in oral praxis assessment showed that while persons with Down syndrome as a group exhibited poor oral praxis skills when compared to the other groups, not all of them were affected equally. There was probably a sub group of persons with Down syndrome who exhibited normal or near normal oral praxis skills. Isolated oral movement tasks alone did not reflect adequate oral praxis skills of individuals independent of oral motor skills. Hence, another task, viz., sequential movement task was also included. This was done to gain more insight into assessment of oral praxis relatively independent of oral motor issues.

B. Sequential oral movements

Oral movements produced in sequence were assessed in this section. Participants were instructed to imitate sequential movements produced by the investigator one after the other as per the protocol. The responses of the subjects were scored for two behaviors:

a. Motor control score, and
b. Sequential motor score.

Both were rated on a scale from 0 to 2. While motor control score (MCS) rated the accuracy of the two movements in sequence, sequential motor score (SMS) was used to rate whether the sequence was maintained or not. These scores were used as raw scores and comparisons across the groups were made using one-way ANOVA. The main effect groups was significant. The results are depicted in Table 15 and figure 7. Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. The other three groups significantly differed from one another both in terms of MCS and SMS at .001 levels of significance.

Table 15: Means, SDs and one-way ANOVA for sequential oral movements.

Sequential oral movements	Down syndrome (DS)		Mental retardation (without DS)		TD children (MA matched)		TD children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Motor control score (MCS)	4.75	2.84	7.82	1.43	9.40	0.82	10.00	0.00	26.57***
Sequential motor score (SMC)	5.85	2.99	8.86	0.91	9.93	0.25	10.00	0.00	23.91***

***p<.001

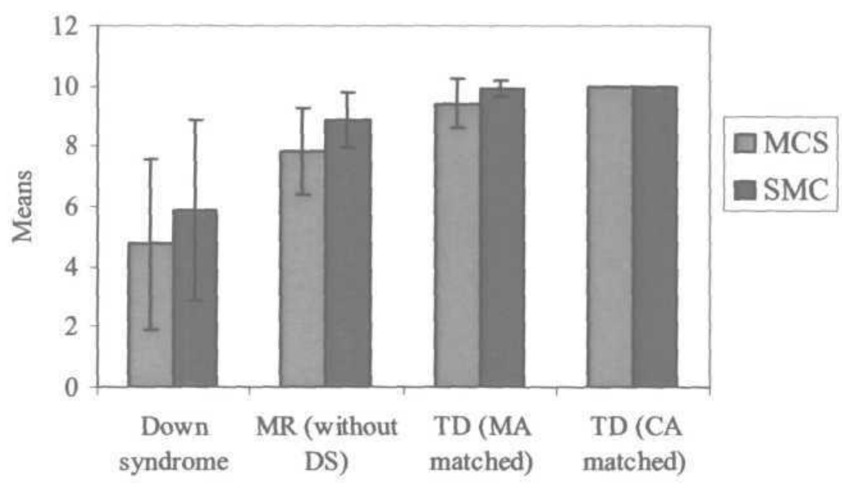

Figure 7: Means and SDs for sequential oral movements

Persons with Down syndrome exhibited significantly greater oral praxis problems in sequential movements than the control groups both in terms of accuracy (MCS) and sequence (SMS). For both MCS and SMS, the scores of persons with Down syndrome ranged from 0 to 10. Persons with mental retardation (without DS) on the other hand, exhibited lesser numbers of errors than persons with DS, but significantly greater numbers of errors than mental age matched typically developing children for MCS. Scores of persons with mental retardation (without DS) for MCS were 5 to 10 and for SMS, they were 8 to 10. In mental age matched typically developing children, the scores for MCS ranged from 9 to 10 and scores for SMS ranged from 8 to 10.

The chronological age matched typically developing children obtained highest scores for all tasks. From the other three groups, i.e. persons with Down syndrome, mental retardation (without DS) and the mental age matched typically developing children, not all persons showed similar performance both in terms of the type of tasks that were affected more and in terms of severity. The percentage of persons affected in sequential oral movements in terms of motor control scores and sequential motor scores are shown in figures 8 and 9 respectively.

As is evident from Figures 8 and 9, persons with Down syndrome had more difficulties with the task of 'blow and smile' in terms of accuracy and with the task 'smile and kiss' in terms of sequence. More numbers of persons with MR (without DS) also had difficulties sequencing 'smile and kiss' and accuracy was affected in more persons for the task 'bite and blow'.

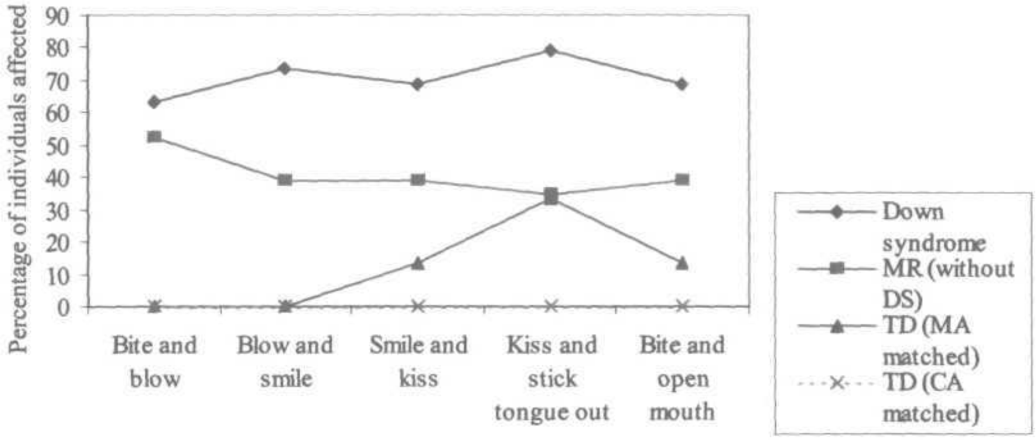

Figure 8: Percentage of persons affected in sequential oral movements (motor control score) tasks across three groups of participants.

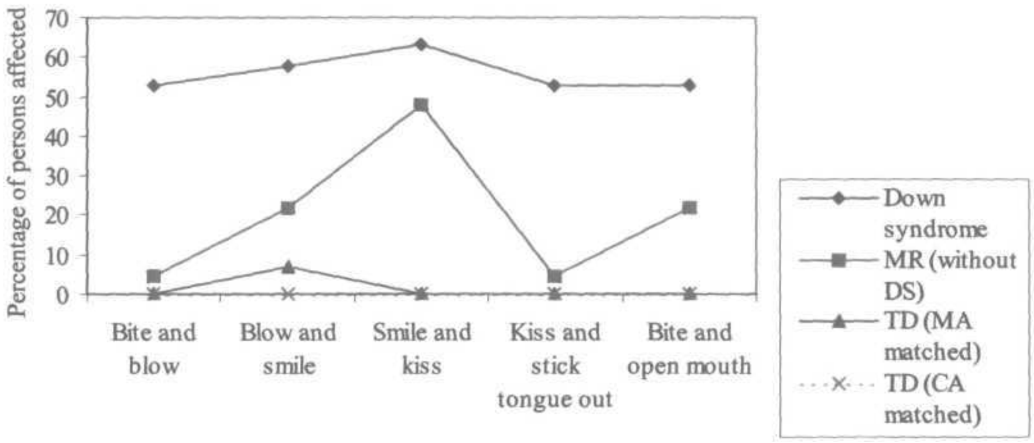

Figure 9: Percentage of persons affected in sequential oral movements (sequential motor score) tasks across three groups of participants.

Approximately 13% of persons with MR (without DS) had protruding and malaligned teeth, and this could be the reason why they exhibited more problems in the tasks that involved biting and kissing. Typically developing children showed a similar pattern of difficulties as persons with mental retardation (without DS). However, much lesser frequencies of persons were affected.

Persons with Down syndrome exhibited distinct difficulties in the ability to organize oral movements. Motor control in terms of sequencing oral movements accurately and in the right order was affected in the group with Down syndrome. No studies have compared double sequential oral motor movement tasks in persons with Down syndrome and mental age matched control groups. Elliott et al. (1990) reported that persons with Down syndrome performed better than persons with mental retardation (without DS) in terms of sequential three-element movements on visual demonstration rather than on verbal instructions. This study has only analyzed two-element oral movements on imitation, i.e. visual demonstration and it may be assumed that three-element movements may be more difficult for the group with Down syndrome. Hence, the results of the study by Elliott et al. (1990) are not the same as those of this study.

Both groups of children with disorders performed poorly on the task of 'smile and kiss' and the mental age matched typically developing children showed poor performance on 'blow and smile'. This could be due to the involvement of two extreme movements in these tasks; one involving retraction of lips, and the other a protrusion. These tasks were difficult for all participants, but persons with Down syndrome had significantly more problems in both sequencing and accuracy of movements. Had the problem been only due to oral motor issues, more specifically hypotonia, then sequence of movements should not have been affected. Sequential oral movements assessment is a more difficult task than isolated oral movements for assessment of oral praxis skills. This is because precise motor control is required for the maintenance of sequential movements than for isolated movements. As the difficulty of tasks increased, oral praxis deficits in the group of persons with Down syndrome became more evident. Breakdown in sequencing is explained as a problem at the praxis level as the loss in the ability to sequence vocal tract gestures (Gracco, 1987), aberrant timing of articulators (Saltzman, 1986) or problems in priming target movements in an appropriate sequence (MacKay, 1970). The result also indicated that sequential oral movement assessment was more sensitive than the isolated oral movement task to evaluate oral praxis skills relatively independently from oral motor skills. Persons with mental retardation (without DS) also exhibited difficulties in sequencing and probably had certain oral praxis deficits as well, albeit not as severe as those of persons with Down syndrome.

The results from the oral praxis assessment indicated that persons with Down syndrome had significantly greater oral praxis problems when compared to the control groups. The isolated oral praxis assessment revealed that while most persons with Down syndrome exhibited deficits in oral praxis skills, there was heterogeneity within the group. Apart from this variability, it was difficult to discern whether the oral praxis was seemingly affected due to oral motor issues or due to oral praxis deficits per se. Sequential oral praxis assessment partly alleviated this concern by evaluating sequence of double oro-motor movements. Chronological age matched typically developing children obtained full scores in all tasks. While accuracy and sequence of oral movements were affected in the other three groups i.e. persons with Down syndrome, mental retardation (without DS) and mental age matched typically developing children, persons with Down syndrome exhibited significantly greater problems than the other groups. It was clear from the results that persons with Down syndrome had some amount of deficits in oral praxis skills. Apart from oral praxis skills, verbal praxis skills were also assessed and are discussed in the following section.

III. Verbal Praxis Skills

Verbal praxis skills were assessed in tasks that increased in complexity ranging from isolated verbal movements to spontaneous speech. Totally six tasks were included and they are as follows:

A. Isolated verbal movements
B. Sequential verbal movements
C. Assessment of diadochokinetic tasks
D. Word level praxis assessment
E. Sentence level praxis assessment
F. Spontaneous speech analysis

While assessments of sequential speech movements and diadochokinetic tasks were not language specific; the other sections included stimuli varying from words to sentences that were prepared specifically in Kannada. Spontaneous speech was also assessed in Kannada and each of these sections will be discussed separately.

A. Isolated verbal movements

Various stimuli ranging from vowels, continuant consonants such as 'm…', 'n…', '1…', 's…', 'sh…' and CV syllables were used to assess isolated verbal movements. CV syllables comprised of all unaspirated consonants used in the initial position in Kannada along with the schwa vowel. Participants were instructed to imitate the verbal stimuli uttered by the investigator. The responses of the subjects were rated based on the accuracy and numbers of repetitions required to elicit the target. A maximum of two repetitions were given if the participant did not imitate the sounds properly and was then rated accordingly on a rating scale of 0 to 3 (with 0 indicating inability to perform even with repetitions) as depicted in Appendix 1.

Each of these tasks was analyzed separately by transcribing the responses of participants. Observations were made, raw scores were tabulated and one-way ANOVA was carried out in order to compare the performance across the groups. Significant differences were seen between the groups. Scores of persons with Down syndrome ranged from 5 to 61 when compared to the scores of persons with mental retardation (without DS) who scored in the range of 55 to 66. Scores of mental age matched typically developing children ranged from 60 to 66. Control group II i.e. chronological age matched typically developing children scored 100% in all tasks, so one-way ANOVA was carried out only on the other three groups. The results are presented in table 16 and figure 10. Duncan's post-hoc test revealed a significant mean difference between persons significantly greater praxis deficits in isolated verbal movements when compared to persons with mental retardation (without DS) and mental age matched typically developing children.

Table 16: Means, SDs and one-way ANOVA for isolated verbal movements.

Verbal praxis assessment	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Isolated verbal movements	44.36	13.48	61.66	2.82	64.66	1.79	66.00	0.00	39.66***

*** p< .001

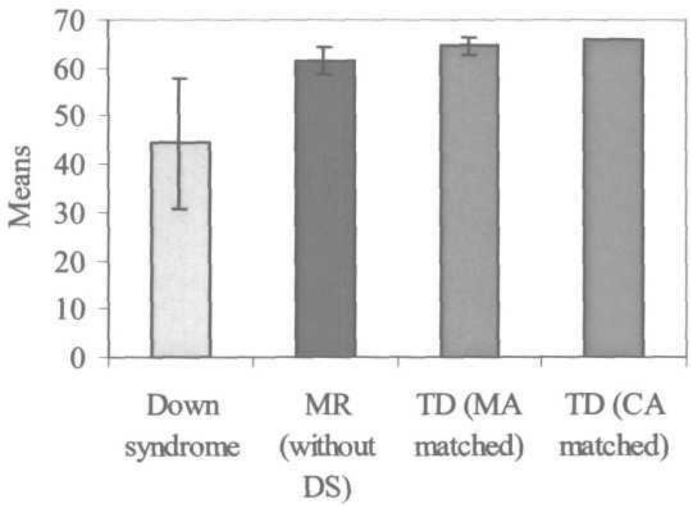

Figure 10: Means and SDs for isolated verbal movements

Although as a group, persons with Down syndrome had poor scores on isolated verbal movements, they exhibited heterogeneity within the group as is evident from the

Although as a group, persons with Down syndrome had poor scores on isolated verbal movements, they exhibited heterogeneity within the group as is evident from the standard deviation value of 13.48 depicted in table 16. From a total score of 66, their scores ranged from as low as 5 to as high as 61 and it is hence evident that not all persons with Down syndrome had the same severity of deficits in isolated verbal movements. Some of them had more severe problems than the rest and some of them even obtained nearly complete scores. Similarly, not all tasks were equally affected amongst all participants in the three groups. The mean raw scores and SDs of isolated verbal movements related to lip, jaw and tongue structures (refer Appendix 1) are depicted in table 17. Since the numbers of items in each of these categories namely, lip, jaw, and tongue movements were not constant, the mean scores were converted to percentage scores in order to compare the performances between the categories of each group. Mean percentage scores for individual structures are depicted in figure 11.

Table 17: Means, and SDs for isolated verbal movements for jaw, lips and tongue.

S.No	Isolated verbal movements	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	Jaw movements	12.50	2.78	14.76	0.50	14.93	0.25	15.00	0.00
2	Lip movements	12.96	2.60	14.96	0.18	15.00	0.00	15.00	0.00
3	Tongue movements	21.50	6.55	31.93	2.77	34.66	1.79	36.00	0.00

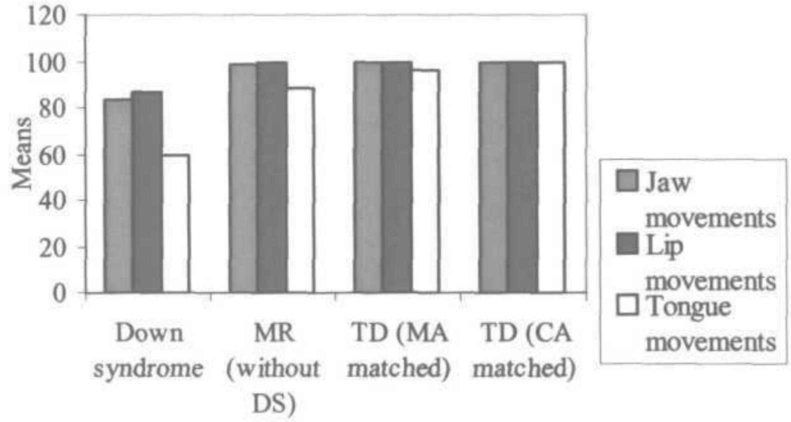

Figure 11: Percentage scores for isolated jaw, lip and tongue movements

Tables 17 and figure 11 depict that the chronological age matched typically developing children achieved highest scores. All three groups obtained higher scores for isolated verbal movements related to lip, followed by jaw and lowest scores for verbal movements involving the tongue. Friedman test was used to find out pair-wise differences between the jaw, lip, and tongue movements within each participant group. Wilcoxon signed rank test was then used to find out which of the categories were significantly different from one another. This comparison was carried out only for the experimental group and control groups I and III i.e. the mental age matched groups- persons with Down syndrome, mental retardation (without DS) and mental age matched typically developing children. This was because the chronological age matched typically developing group i.e. control group II obtained 100% scores in all tasks.

Table 18: Friedman test depicting pair wise comparisons of isolated verbal movements of lip, jaw, and tongue within each participant group.

S.No.	Isolated verbal movements	Down syndrome (DS)	Mental retardation (without DS)	Typically developing Children (MA matched)
	Pairs	| z |	| z |	|z|
1	Jaw-lip movements	1.31	2.12	1.00
2	Jaw-tongue movements	4.56***	4.63***	2.53*
3	Lip-tongue movements	4.78***	4.56***	2.39*

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

It is evident from table 18 that all three groups exhibited a similar trend in terms of differences within groups. Speech sounds that involved predominantly lip movements were least affected followed by those involving jaw movements. Speech sounds that involved predominantly tongue movements exhibited most errors amongst all three groups. Wilcoxon signed rank test showed that significant differences were present between jaw-tongue movements and jaw-lip movements but not between lip and jaw movements. When individual sounds and percentage of individuals for those sounds were taken into account, tongue movements were most affected, as revealed in figure 12.

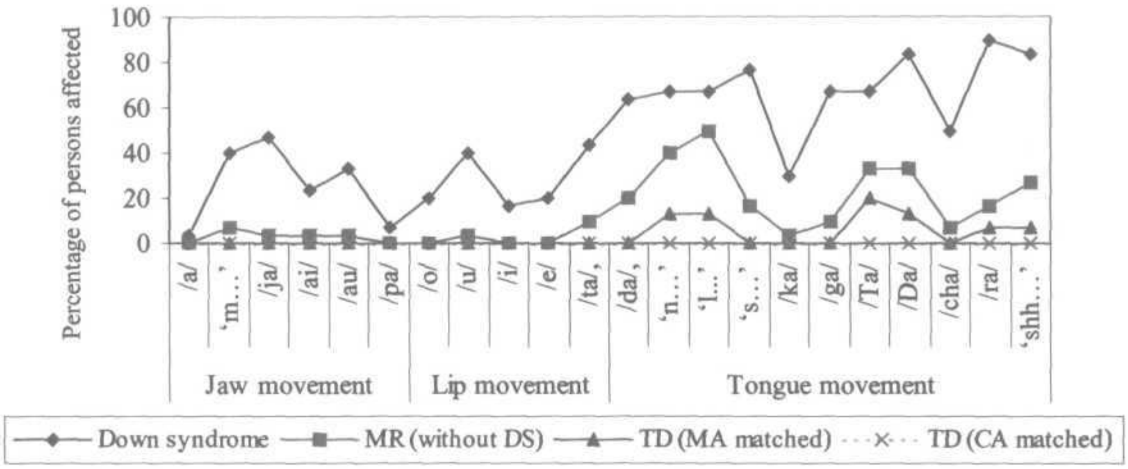

Figure 12: Percentage of persons affected in isolated verbal movement tasks across the four groups of participants.

Figure 12 revealed that the continuant /s/ consonant was affected in most persons with Down syndrome unlike the control groups where more persons seemed to have difficulty in producing the continuant /l/ consonant, perhaps due to difficulty in producing the sound continuously. It may also be noted that most persons in the control groups were able to utter '1...' continuously but after repetition of instructions. Of the persons with mental retardation (without DS) that had difficulties with this task, more than half of them obtained a score of 2 i.e. they were able to imitate the task, but with repetitions. Amongst typically developing children, most children were unable to imitate the retroflex voiceless stop /t/ that they substituted with its dental counterpart /t/. Retroflex stops are generally acquired later in typically developing children in Kannada (Shyamala & Basanti, 2003). While persons with Down syndrome also had difficulty in producing /l/ and /t/, more persons had difficulty producing the fricative /s/. Fricatives require greater precision of articulators and were considered more difficult sounds for persons with Down syndrome (Van Borsel, 1988) and were also found to be acquired late (Zisk & Bialer, 1976; Bleile, & Schwarz, 1984). Similar patterns in terms of percentage of persons affected were evident from figure 12. For most other tasks, higher numbers of persons with Down syndrome were affected followed by persons with mental retardation (without DS) and then the typically developing children.

Verbal praxis assessment with tasks including isolated verbal movements may be considered easiest and hence came first in the hierarchy of items. The results of this task indicated significant differences between the experimental groups i.e. persons with Down syndrome and the two control groups. However, there was variability within the group with Down syndrome indicating that not all persons were affected to the same degree. Also, while persons with Down syndrome had more problems in producing the continuant's', the other two groups had more difficulty in producing the continuant '1'. But it may be noted that most of these participants in the control groups were able to produce the continuant T sound, but with repetitions. These tasks however, cannot be considered as sensitive tasks for verbal praxis assessment, because persons might have exhibited errors due to oral motor problems such as, hypotonia. Other tasks involving imitation of sequences of speech sounds were hence included to better evaluate the presence of verbal praxis difficulties in persons with Down syndrome.

B. Sequential verbal movements

Two-sound and three-sound combinations of vowels and continuant */ml* consonant in Kannada were used as stimuli in this task. As in the section of sequential oral movements, the responses were assessed in terms of motor control score (MCS) in order to evaluate the accuracy of the responses and sequential motor score (SMS) to evaluate the adequacy of the sequence of verbal movements. The rating was done on a scale of 0 to 2, with 0 representing low scores as given in Appendix 1. Raw scores of persons with Down syndrome for MCS ranged from 0 to 13 and for SMS, the raw scores ranged from 0 to 10. On the other hand, raw scores of persons with mental retardation (without DS) ranged from 10 to 14 and for SMS, they ranged from 6 to 14 for MCS. Mental age matched typically developing children scored in a higher range for both MCS and SMS in the range of 11 and 12 to 14 respectively.

Table 19 and figure 13 show the group means and SDs for sequential verbal movements. Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. A significant main effect of groups was found. From Table 19 and figure 13, it is seen that significant differences were present across the four groups of participants. Duncan's post-hoc test revealed that persons with Down syndrome obtained significantly lower scores when compared to the control groups at .001 levels of significance.

Table 19: Means, SDs and one-way ANOVA for sequential verbal movements.

Sequential verbal movements	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Motor control score (MCS)	7.60	3.51	12.82	1.20	12.80	1.08	14.00	0.00	35.39***
Sequential motor score (SMC)	3.75	3.04	11.21	2.02	13.33	0.81	14.00	0.00	95.13***

*** p< .001

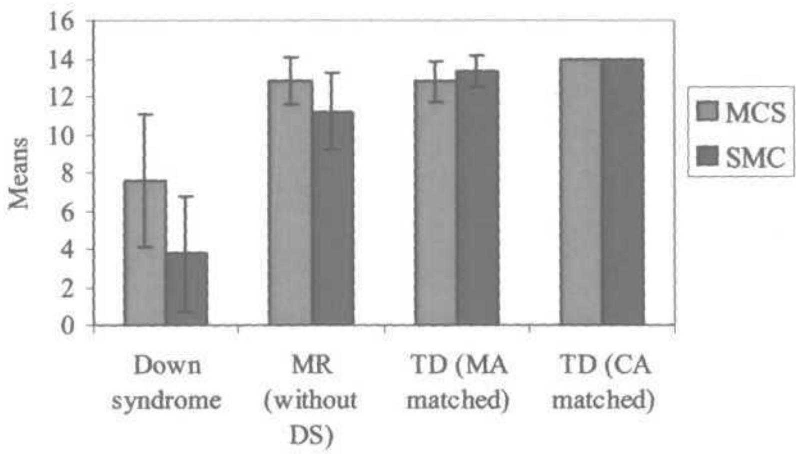

Figure 13: Means and SDs for sequential verbal movements

While control groups I and III i.e. the mental age matched control groups did not differ from each other in the 'motor control score', persons with mental retardation (without DS) exhibited significantly poorer scores than typically developing children in the 'sequential motor score'. The results revealed that persons with Down syndrome exhibited poorer accuracy and sequencing of two and three-sound movements. Persons with mental retardation (without DS) also exhibited sequencing problems when compared to typically developing children indicating that they perhaps had verbal praxis deficits as well, but not as severe as in persons with Down syndrome. The chronological age matched typically developing children obtained full scores for all tasks.

The other three groups that were mental age matched, not all persons in these groups showed similar performance both in terms of the type of tasks that were affected more and in terms of degree of problems. This can be observed in figures 14 and 15 that depict the percentage of individuals affected in motor control scores and sequential motor scores respectively.

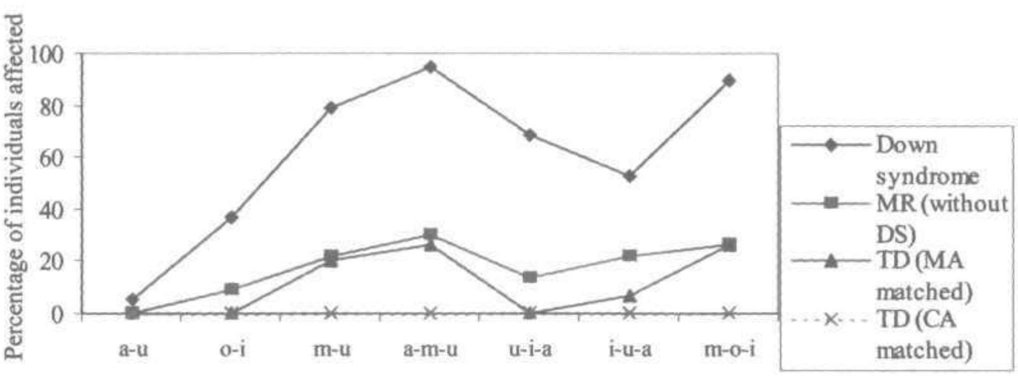

Figure 14: Percentage of persons affected in sequential verbal movement (motor control score) tasks across the four groups of participants.

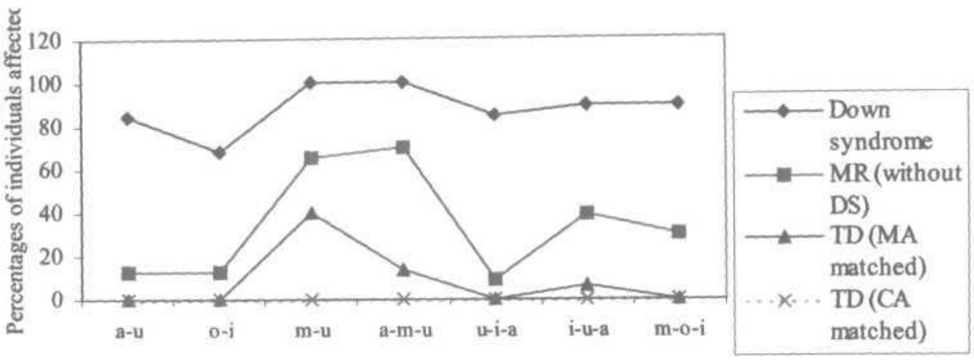

Figure 15: Percentage of persons affected in sequential verbal movement (sequential motor score) tasks across the four groups of participants.

From figure 14, it is seen that the numbers of persons in each group that exhibited problems in accurate production (motor control score) and the hierarchy of these difficulties followed a similar pattern across the three groups. All three groups had difficulties in the accurate production of 'a-m-u', followed by 'm-o-i' and 'm-u'. While 94.73% of persons with Down syndrome exhibited difficulties in imitating 'a-m-u' sequence, 30.43% of persons with mental retardation (without DS) and 26.66% of typically developing children exhibited difficulties in this task.

From figure 15, it is evident that in terms of sequential motor scores, while 'a-m-u' and 'm-u' were affected in all persons with Down syndrome, they were affected in 68.56% and 65% of persons with MR (without DS). On the other hand, sequential motor scores for these two tasks were affected in 40% and 13.33% of typically developing children respectively. Sequence was affected most for 'a-m-u' followed by 'i-u-a' in 13.33% and 6.66% of typically developing children. Tasks involving the use of 'm…'

continuant consonant were affected in all participants perhaps because most participants tended to use /mə/ as a syllable instead of using the nasal continuant without a vowel.

The results as evident from sequential verbal movement tasks indicate that amongst the three groups of participants, persons with Down syndrome exhibited greater numbers of errors in sequential verbal tasks both in terms of accuracy (MCS) and sequencing (SMS). Persons with mental retardation had significantly poor sequencing (SMS) scores when compared to typically developing children indicating a certain amount of verbal praxis difficulty in this group as well. Not much variability within groups was noticed in the sequential verbal movements section of verbal praxis assessment. In general, most persons in the three groups found the same types of tasks more difficult than the rest as is evident in the figures 14 and 15. More persons had difficulties in tasks involving 'm…' continuant consonant amongst all three groups of participants. This assessment of verbal praxis helped to alleviate the concern of assessing verbal praxis independently from oral motor difficulties such as, hypotonia by using the sequential motor score. Sequential motor scores (SMS) assessed only the sequencing ability of the participants and not the accuracy of movement, which was assessed separately using MCS. Thus, it enabled assessing verbal praxis skills rather than addressing the motor execution problems. A breakdown in sequencing is a problem of praxis breakdown rather than that of execution. It has been explained as the loss in the ability to sequence vocal tract gestures (Gracco, 1987), aberrant timing of articulators (Saltzman, 1986) or problem in priming target movements in an appropriate sequence (MacKay, 1970). Persons with mental retardation (without DS) also exhibited sequencing errors, but significantly lesser than in persons with Down syndrome. Sequencing and speed of movements of articulators were also corroborated and tested in another task of assessment of diadochokinetic tasks.

C. Assessment of diadochokinetic tasks

Diadochokinetic tasks were assessed by asking the participants to repeat syllables /pə/, /ʈə/, /kə/ (Alternate Motion Rates-AMR) and /pəʈəkə/ (SMR-Sequential Motion Rates) as accurately and as fast as they could. When the participants did not understand that they had to repeat as fast as possible, they were provided a model as to how to repeat the syllable fast by tapping a finger while uttering the syllables quickly. They were allowed five attempts and the best attempt was considered for calculation. Only attempts with a minimum of ten iterations were considered. Continuously uttered and clearly enunciated segments of iterations were marked using software called 'Wavesurfer', an open source tool for sound visualization and manipulation (Sjolander, & Beskow, 2005). The time taken for ten iterations was analyzed using the software and iterations per second were then derived using the formula:

$$DDK\ Rate = \frac{10}{\text{Time taken in seconds for ten iterations}}$$

These tasks were found to be more difficult for some of the participants especially in the group with Down syndrome. Table 20 illustrates the different types of difficulties and errors exhibited by the three groups of participants.

Table 20: Types of difficulties and errors in DDK assessment shown by participants.

S.No	Types of difficulties and errors	Numbers of persons		
		Down syndrome (DS)	Mental retardation (without DS)	Typically developing children
1.	Uncooperative behaviour	5	3	0
2.	Inability to perform any of the four tasks	4	0	0
3.	Inability to maintain sequence of /pəʈəkə/	12	0	0
4.	Incorrect production of all utterances	2	0	0
5.	Incorrect production in one of four tasks wrong	0	5	0
6.	Production of less than 10 iterations	6	3	0
7.	Production of unclear utterances	2	0	0

It is evident from the table 20 that the data obtained from persons with Down syndrome was less compared to the two groups owing to more numbers of them exhibiting difficulties in the DDK tasks. Of particular significance is the observation that twelve of them had difficulties in maintaining sequence of /pəʈəkə/. It may also be noted that persons with Down syndrome required more attempts than the other two control groups in performing the SMR task of /pəʈəkə/. Comparisons across the groups were made in terms of rate (iterations per second), numbers of attempts and consistency.

Comparisons across groups in terms of rate of syllable repetitions (iterations/second)

Iterations per second for the AMR and SMR tasks were tabulated for the four groups of participants. Comparisons across the groups were then made across the groups by using one-way ANOVA. A significant main effect of groups as depicted in table 21 was found for the SMR tasks.

Table 21: Mean scores of rate (iterations/sec) obtained for the participants.

DDK	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(3,86)
/pa/	5.00	1.09	5.24	1.09	5.81	0.59	5.88	0.60	3.07
/ʈə/	4.53	1.55	5.08	0.98	5.53	0.96	5.61	0.88	2.28
/kə/	4.62	1.21	4.83	1.41	5.55	0.41	5.54	0.20	2.78
/pəʈəkə/	4.07	2.18	6.83	2.14	8.03	1.34	8.50	1.03	8.16***

***p<.001

It is evident from table 21 that significant differences were present only for the SMR task and not for the AMR tasks. For the SMR tasks, Duncan's post-hoc test indicated that persons with Down syndrome produced significantly less numbers of iterations per second when compared to the other control groups. The three control groups did not differ significantly from each other. Persons with Down syndrome were hence able to utter the same syllable repeatedly more easily compared to repeating three different syllables one after another. In persons with Down syndrome, praxis difficulties have been reported in terms of slow DDK rates and in particular, difficulties in the repetition of /p-t-k/ using electropalatography (EPG) (Hamilton, 1993). However, in another study that involved EPG, McCann and Wrench (2007) concluded that reduced rates did not characterize the DDK performance of persons with Down syndrome. Sequencing of sounds in SMR tasks were found to be particularly problematic in persons with Down syndrome. Sequencing problems in SMR tasks when compared to AMR tasks have also been reported in persons with CAS (Thoonen et al., 1996). Sequencing is reported to be a major problem in persons with praxis difficulties i.e. children with CAS. The problem in sequencing is indicative of praxis breakdown (MacKay, 1970; Saltzman, 1986; Gracco, 1987) and is clearly evident by greater problems exhibited in SMR tasks rather than in AMR tasks.

Comparisons across groups in terms of numbers of attempts

A maximum of five attempts were allowed for each child. The attempts taken by each participant were tabulated for AMR and SMR tasks. The raw scores in terms of numbers of attempts were then subjected to statistical analysis using one-way ANOVA. The main effect of groups was significant for all the DDK tasks.

Table 22: Means, SDs and one-way ANOVA for numbers of attempts by participants for AMR and SMR tasks

DDK	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F (3,86)
/pə/	2.92	1.44	1.82	1.11	1.33	0.48	1.03	0.42	7.93**
/ʈə/	3.11	2.42	1.42	0.92	1.18	0.40	1.01	0.32	7.64**
/kə/	3.09	1.92	1.25	0.55	1.13	0.35	1.10	0.33	14.55***
/pəʈəkə/	3.25	2.91	1.39	0.65	1.53	0.51	1.32	0.45	6.40**

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

It is evident from table 22 that persons with Down syndrome used more attempts to carry out all tasks when compared to the three control groups. Duncan's post-hoc test revealed that the three control groups did not differ from each other in terms of numbers of attempts taken. Persons with Down syndrome took significantly greater numbers of trials than the control groups. Numbers of attempts have been considered important measures to evaluate the DDK tasks of children with CAS. Children with praxis breakdown or CAS to use more attempts than persons with spastic dysarthria and typically developing children (Thoonen et al., 1996) and this measure has been used to differentially diagnose CAS from spastic dysarthria. These results are also in support of Rosin et al. (1988) who have stated that persons with Down syndrome required more cues than persons with mental retardation (without DS) and typically developing children.

Comparisons of groups in terms of accuracy of production

Accuracy is considered an important measure for DDK analysis in 3 to 4 year old typically developing children (Williams & Stackhouse, 2000). Responses from all participants were noted and were rated for accuracy in terms of articulation. If the first five repetitions were accurately produced, a score of 1 was given and 0 if the repetitions were inaccurate. The chronological age matched children did not produce any errors and hence the other three groups, namely, persons with Down syndrome, mental retardation (without DS) and mental age matched typically developing children were included. The responses were tabulated and subjected to statistical analysis using one-way ANOVA.

Table 23 depicts the means, SDs and F values for rating of accuracy of responses in AMR and SMR tasks. The main effect of groups was significant for all DDK tasks. Higher mean scores in table 23 indicated better accuracy and it is evident that persons with Down syndrome obtained the lowest scores amongst the three groups that were compared. Duncan's post-hoc test revealed that the experimental group i.e. persons with Down syndrome significantly differed from the two control groups. On the other hand, control groups I (persons with mental retardation) and III (mental age matched typically developing children) did not differ significantly from one another.

Table 23: Means, SDs and one-way ANOVA for accuracy of responses in DDK tasks

Accuracy in DDK tasks	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
/pə/	0.70	0.47	1.00	0.00	1.00	0.00	8.56**
/ʈə/	0.40	0.50	0.88	0.32	0.93	0.25	12.19***
/kə/	0.65	0.48	0.96	0.19	1.00	0.00	7.78**
/pəʈəkə/	0.25	0.44	0.88	0.32	1.00	0.00	29.22***

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

The accuracy was also analyzed in terms of placement, voicing, perseveration, deletion, insertion and exchange errors as defined by Yaruss and Logan (2001) and considered as nonsystematic articulation errors. Figure 16 depicts the different types of articulatory errors noticed in the three groups of participants.

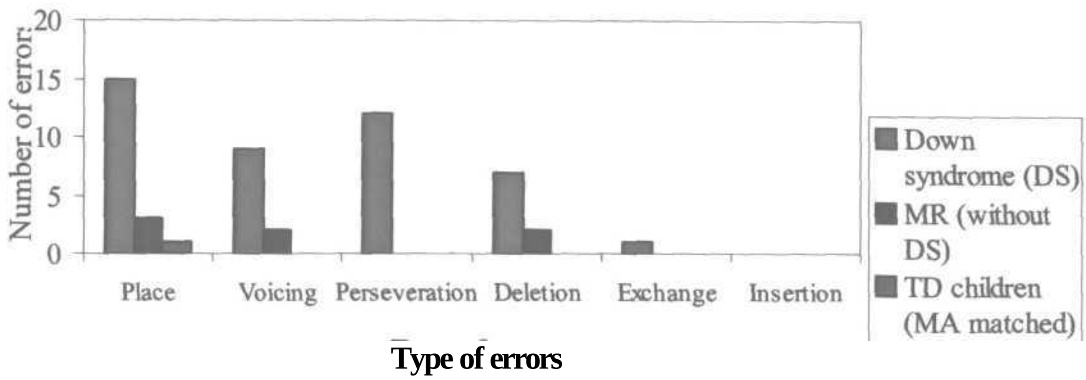

Figure 16: Nonsystematic articulatory errors observed in DDK tasks

It is evident from figure 16 that persons with Down syndrome exhibited greater numbers of place, voicing, perseveration, and deletion errors when compared to the control groups. None of the participants made insertion errors, and exchange errors were noted only in persons with Down syndrome. The mental age matched typically developing group had only place errors.

Comparisons of groups in terms of consistency of production

Consistency of syllable productions in SMR tasks is considered an important measure to evaluate sequencing difficulties that often exist in persons with persisting speech difficulties (Williams & Stackhouse, 2000). The chronological age matched children did not produce any errors and hence the other three groups, namely, persons with Down syndrome, mental retardation (without DS) and mental age matched typically developing children were included.

Consistency was evaluated in the participants by rating their responses for consistency of syllable productions on a rating scale of 0 to 3 where 0 represented the lowest score. These ratings were used as raw scores and were subjected to statistical analysis using one-way ANOVA. There were significant differences between the groups. Table 24 and figure 17 depict the means, standard deviation and F values for the SMR task.

Table 24: Means, SDs and one-way ANOVA for consistency in SMR task

DDK	Down syndrome (DS)		Mental retardation (without DS)		TD children (MA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Consistency in /pəʈəkə/	1.66	1.11	2.84	0.50	3.00	0.00	17.19***

*** p< .001

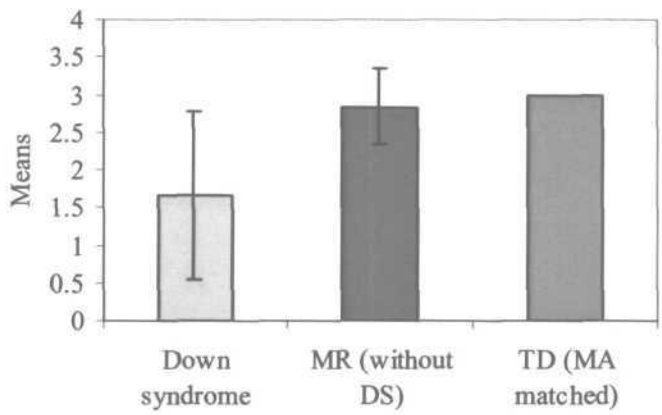

Figure 17: Means and SDs of consistency in repetitions of the SMR task

From table 24 and figure 17 it is evident that persons with Down syndrome obtained lower scores than the control groups. They had more problems in maintaining consistency of the /pəʈəkə/ syllables across the first four utterances, i.e. they had greater token to token variability than the two control groups namely persons with mental retardation (without DS) and typically developing children (MA matched). Duncan's post-hoc test revealed that the two control groups did not vary significantly from each other. Inconsistent errors characterize the speech of persons with CAS (Robin, 1992; Davis et al., 1998; Forrest & Morrisette, 1999; Nijland et al., 2002; Forrest, 2003; Nijland et al.; 2003) and there are also a few reports of inconsistent speech errors in persons with Down syndrome (Dodd, 1976). However, no studies have evaluated consistency in DDK tasks in persons with Down syndrome. But consistency in DDK tasks is considered as an important parameter in the profile of assessment of persons with praxis difficulties (Crary, 1993).

Results from DDK assessment have shed important information regarding verbal praxis deficits in persons with Down syndrome. DDK tasks were evaluated on the basis of rate, numbers of attempts, accuracy and consistency. In terms of rate, significant differences were observed in the SMR tasks between persons with Down syndrome and the control groups. These results were in support of findings of Thoonen et al. (1996) in persons with CAS and of McCann and Wrench (2007) in persons with Down syndrome. Comparison of the groups in terms of attempts, and accuracy of AMR and SMR tasks revealed significant differences between persons with Down syndrome and the control groups for all tasks. Comparison across the groups in terms of consistency in SMR tasks also revealed significant differences between persons with Down syndrome and the control groups. In summary, persons with Down syndrome performed poorly on DDK tasks in terms of rate (in SMR tasks), numbers of attempts taken, accuracy and consistency implying that they have greater praxis deficits than persons with mental retardation (without DS) and mental age matched typically developing children.

D. Word level

Analysis of verbal praxis skills at word level involved a 40-word imitation task that included disyllabic, trisyllabic, and multisyllabic words in Kannada with and without clusters (geminated and non-geminated). The following steps were involved in selecting the words:

- A corpus of 180 words was selected from picture books for children.
- The 180 words were short listed by two speech language pathologists to 60 commonly occurring words. The 60 words were then were then rated for their degree of familiarity by typically developing children.
- Thirty 4-5 year old typically developing children who were not included in the control groups rated these sixty words for their familiarity on a three point rating scale ('0'- I don't know this word; '1'- I have heard it, but don't know what it means; '2'-1 know this word well)
- 30 words that were rated to be most familiar by the 4-5 year old typically developing children were retained in the final list.

- In order to include more complex words, another list of 100 words with two and three clusters was prepared from a Kannada dictionary. Ten words were short-listed.
- The 40-word list was vetted by a linguist to check for dialectal appropriateness of the words amongst the Bangalore-Mysore Kannada speaking persons.

During data collection, the participants in the experimental and control groups were instructed to repeat the words after the investigator. The imitated samples obtained from the participants were transcribed using the broad IPA system of transcription. Segment-to-segment inter-judge reliability of the transcribed samples was 78.02%. Intra-judge reliability was also measured by retranscribing 10% of the samples after two weeks by another judge; it was found to be 82.89%. Various aspects of phonological errors were computed from the transcribed utterances and these are presented in the order given as follows:

1. Phonological process assessment
   a. Types of phonological processes
   b. Percentage occurrence of the phonological processes
   c. Frequency of persons exhibiting various phonological processes
2. Aspects that suggest verbal praxis deficits
3. Sequence maintenance score
4. Other errors

1. Phonological process assessment

a. Types of phonological processes

The words imitated by all participants were transcribed and phonological process errors were computed. Control group II i.e. chronological age matched typically developing children did not exhibit any phonological errors. Since phonological processes generally disappear by the age of 7 years in typically developing children (Stoel-Gammon & Dunn, 1985), it was considered more meaningful to compare the groups with disorders with the mental age matched typically developing children.

Persons with Down syndrome and the two control groups i.e. persons with mental retardation (without DS) and mental age matched typically developing children were compared in terms of the percentage occurrences of the types of phonological processes that were observed in the three groups. All phonological processes were classified into 'space', 'timing' and 'whole-word errors' in order to comment on the contribution of these error types to praxis control. Velleman (2003) recommends this method for the description of phonological errors in persons with Childhood Apraxia of Speech (CAS). The specific features analyzed under the space, timing and whole word errors are as follows:

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

The phonological processes under space, timing and whole word errors and their presence or absence in the three groups are depicted in table 25. It is evident from table 25 that persons with Down syndrome produced more phonological processes than the two control groups. A total of 38 different types of phonological processes were identified in the group with Down syndrome, when compared to 30 and 16 in mental age matched persons with mental retardation and typically developing children.

In table 25, the tick (V) mark indicates presence and (--) mark indicates absence of the corresponding phonological process in the group. 'DS', 'MR' and 'TD' represent the different groups namely persons with Down syndrome, mental retardation (without DS) and typically developing children (mental age matched) respectively.

Table 25: Types of phonological processes that were observed in the participant groups.

SNo.	Types of phonological processes with examples	Participant groups		
		DS	MR	TD
	I. Space errors			
1.	*Fronting*			
a.	Fronting of velars Replacement of velars /k/, /g/ and /ŋ/ to a more anterior position, generally an alveolar stop is considered as fronting in English. In the present analysis replacement of velars with retroflex and dental stops was also considered since retroflex sounds are also present in Kannada. Examples: /bekku/→[bettu] meaning 'cat' /teŋginəka:ji/→[təndeka:ji] meaning 'coconut'	✓	✓	--
b.	Fronting of retroflex stops Replacement of retroflex stops /ʈ/, /ɖ/, by their dental (/t/, /d/) counterparts was considered as fronting of retroflex stops. Examples: /huɖugi/→[hudgi] meaning 'girl' /kiʈəki/→[kitəki] meaning 'window'	✓	✓	✓
c.	Fronting of /ɭ/ and /ɳ/ Replacement of retroflex nasal continuant /ɳ/ and lateral /ɭ/ to their alveolar (/n/, /l/) counterparts was considered as fronting of ɭ and ɳ. Examples: /ba:ɭehəɳɳu/→[ba:leənnu] meaning 'banana' /ba:ʧəɳige/→[ga:sənige] meaning 'comb'	✓	✓	✓
d.	Fronting of dental stops to bilabial stops Replacement of dental stops /t/, /d/, and /n/ by bilabial /p/, /b/, or /m/ sounds was considered as fronting of dental stops to bilabial stops. Examples: /de:vəst^{h}ana/→[bəsəta:na] meaning 'temple' /teŋginəka:ji/→[menika:ji] meaning 'coconut'	✓	--	--
2.	*Backing*			
a.	Backing of bilabial stops This was defined as the substitution of bilabial stops /p/, /b/, /m/ with stops produced further back in the oral cavity including dental, palatal and velar places stops. This was not a commonly occurring process. Examples: /se:bu/→[se:gu] meaning 'apple' /da:ɭimbe/→[kəɭəbbe] meaning 'pomegranate'	✓	✓	--

SNo.	Types of phonological processes with examples	DS	MR	TD
b.	Backing of dental stops This was defined as the replacement of dental stops /t/ and /d/ by their palatal (retroflex) or velar counterparts. Examples: /ku:dəlu/→[ku:ɖəlu] meaning 'hair'	✓	✓	
3.	*Vowel deviations*			
a.	Vowel centralization Any vowel when changed into the central vowel /ə/ was considered as vowel centralization. Examples: /huɖugi/→[ɔɖəgi] meaning 'girl' /teŋginəkaji/→[təndeka:ji] meaning 'coconut'	✓	✓	✓
b.	Vowel prolongation This error was observed in multisyllabic words where syllable deletions occurred concurrently with vowel prolongation, probably in order to compensate for the reduction in length of the word. An instance of vowel prolongation associated with degemination was also observed. Examples of vowel prolongation with syllable deletion: /ʧəməʧə/→[mə:ʧə] meaning 'spoon' Examples without syllable deletion (with degemination): /kənnəɖəka/→[kə:nəɖəka] meaning 'glasses'	✓	✓	--
c.	Vowel shortening Vowel shortening occurred when a long vowel was perceived as reduced in length. This error was sometimes associated with gemination, probably as a trade-off with the additional 'stress' on the consonant. It was also observed without any involvement of gemination. Examples with gemination: /ga:ɭipaʈa/→[gaɭipatta] meaning 'kite' /se:bu/→[sebbu] meaning 'apple' Examples without gemination: /ba:gilu/→[bugəlu] meaning 'door'	✓	✓	--
d.	Vowel raising A low vowel when raised to a higher position was considered as vowel raising (Pollock, & Keiser, 1990). Examples: /da:ɭimbe/→[da:lambi] meaning 'pomegranate' /se:bu/→[si:bu] meaning 'apple'	✓	--	--
e.	Vowel lowering A high vowel produced as a lower vowel was considered as vowel lowering (Pollock, & Keiser, 1990). Examples: /pustəka/→[kotasa] meaning 'book' /huɖugi/→[hoddi] meaning 'girl'	✓	✓	--

SNo.	Types of phonological processes with examples	DS	MR	TD
f.	Monophthongization or diphthong reduction When a diphthong was changed into a vowel it was defined as monophthongization or diphthong reduction. Only one opportunity of occurrence for this error was present but the observed frequency of occurrence was significantly high in persons with Down syndrome than in the two comparison groups. Examples: /vaidja/-[vedda], [vedja], [vədja] meaning 'doctor'	✓	✓	
g.	Vowel decentralization This process was operationally defined as the substitution of the schwa vowel with a vowel involving both a change of height and/or space (front/back). This may be considered as an idiosyncratic error since a vowel that was easier to produce was changed to a more difficult one. Examples: /ərəmane/→[ədomənе] meaning 'palace' /swəʧʧa/→[wokka] meaning 'clean'	✓	✓	--
4.	Palatalization of alveolar fricative /s/ This was defined as the replacement of the alveolar fricative /s/ by the palatal /ʃ/. Examples in DS: /si:re/→[ʃi:re] meaning 'saree' (an attire)	✓	✓	--
5.	Depalatalization of palatal fricative /ʃ/ This was defined as the substitution of an alveolar fricative by a palatal fricative. Examples: /prəʃne/→[prəsəne] meaning 'question' /kriʃna/→[kisna] meaning 'Krishna' (name of a God)	✓	✓	✓
	II. Timing errors			
1.	Gliding of laterals (/r/, /l/) and fricative /s/ Substitution of a glide for a prevocalic liquid (Bernthal, & Bankson, 1993) was considered as gliding. Examples: /si:re/→[si:je] meaning 'saree' /təle/→[təje] meaning 'head'	✓	✓	✓
2.	Stopping Traditionally stopping is considered as the substitution of stops for fricatives and affricates. In the present analysis, stopping of liquids and glides was also considered based on the inclusive definition by Lowe (1996). Stopping in the initial position is reportedly more commonly observed; however it was observed in initial and medial positions of words in this study. Examples: /si:re/→[ti:re] meaning 'saree' /ʧəppli/→[təppəli] meaning 'slippers'	✓	✓	✓

SNo.	Types of phonological processes with examples	DS	MR	TD
3.	Deaffrication of affricates (to fricatives) This refers to the replacement of an affricate with a stop or fricative, but in the present analysis only the substitution of fricatives for affricates was considered; the former substitution was considered as stopping. Examples: /ʧəppəli/→[səppi] meaning 'slippers' /ba:ʧəɲige/→[ga:sanige] meaning 'comb'	✓	✓	--
4.	Affrication of fricatives This was defined as the incomplete stoppage of fricatives (Velleman, 1998), i.e. when a fricative was replaced with an affricate sound. In the words selected for imitation, the palatal fricative /ʃ/ was present in clusters only and hence this phonological was counted along with cluster reduction. Examples: /kriʃɳa/→[kiʧʧi] meaning 'Krishna'	✓	✓	✓
5.	Denasalization of nasal continuants This was defined as the replacement of nasals by stops whose place of articulation was similar to the target sound (Bernthal, & Bankson, 1993). Examples: /ʧəməʧə/→[ʧəpə:ʧə] meaning 'spoon' /da:ḷimbe/→[da:ḷibbe] meaning 'pomegranate'	✓	--	--
6.	Postvocalic devoicing It was defined as a process when a voiced obstruent that was followed by a vowel became voiceless (Pena-Brooks, & Hegde, 2000). Examples: /a:lugəḍḍe/→[a:kətte] meaning 'potato' /kənnəḍəka/→[kənnəṭəka] meaning 'glasses'	✓	✓	--
7.	Prevocalic voicing This was defined as a process when a voiceless sound preceding a vowel became voiced (Pena-Brooks, & Hegde, 2000). It is said to affect mostly stops and in the present analysis, only stops were considered. Examples: /kiṭəki/→[kiḍəki] meaning 'window' /ga:ḷipəṭa/→[ga:lbədda] meaning 'kite'	✓	✓	✓
8.	*Others* These processes include those that have not been traditionally reported in the literature for English and Dutch			
a.	Substitution of singleton consonants for geminated clusters (degemination) This was considered when a geminated cluster lost its geminate quality and was replaced by its singleton counterpart. Examples: /bekku/→[bæku] meaning 'cat /kənnəḍəka/→[kə:nəḍəka] meaning 'glasses'	✓	✓	✓

SNo.	Types of phonological processes with examples	DS	MR	TD
b.	Substitution of geminated clusters for singleton consonants (gemination) This was defined as a process that occurred when more 'stress' was placed on the singleton consonant so that it acquires a 'geminate' quality. It was considered by Rama Devi (2006) as an atypical phonological process. This process was often associated with syllable deletions in the medial position and vowel shortening. Examples with syllable deletions: /kiʈəki/→[kitti] meaning 'window' Examples with vowel shortening: /ku:dəlu/→[kuddəlu] meaning 'hair' Examples without syllable deletions or vowel shortening: /ga:ɭipəʈa/→[ga:lipətta] meaning 'kite'	✓	✓	✓
	III. Whole word errors			
1.	Cluster reduction This was considered as the substitution of some or all members of a cluster. It included either deletion of a member in a cluster, or all members replaced by a single sound that was not a member of the target cluster (Stoel-Gammon, & Dunn, 1985). Examples of deletion of one member of the cluster: /ʧʰətri/→[əti] meaning 'umbrella' Examples of substitution by a sound that is not a member of the cluster: /su:rja/→[su:la] meaning 'sun'	✓	✓	✓
2.	Consonant deletion: Omissions of singleton consonants in all positions of the word except the final position were considered in this study since final consonants are not common in colloquial Kannada (Hiremath, 1980). Traditionally, initial consonant deletions and final consonant deletions have been reported in the literature. However, consonant deletions in the medial position were also observed in persons with Down syndrome in the present study. Examples of initial consonant deletion /təʈʈe/→[ette] meaning 'plate' Examples of consonant deletion in medial position /teŋginəka:ji/→[təndekaji] meaning 'coconut'	✓	✓	--
3.	Epenthesis Insertion of any consonant or vowel in a given word (Velleman, 1998) was considered as Epenthesis. This analysis was carried out separately from that of epenthesis in clusters. Examples: /a:lugəɖɖe/→[əndəgəɖɖe] meaning 'potato'	✓	✓	✓

SNo.	Types of phonological processes with examples	DS	**MR**	**TD**
4.	Epenthesis in clusters only Traditionally epenthesis has been defined as the insertion of an unstressed vowel, usually schwa /ə/, typically inserted between two contiguous consonants that make up the original cluster. For the present analyses, insertions of the schwa vowel in non-geminated clusters in any word position were considered. Examples: /vaidja/→[vaidəja] meaing 'doctor' /prəʃne/→[prəsəne] meaning 'question'	✓	✓	✓
5.	Migration This involved movement of elements from their locations within the adult word. In migration, one element moves elsewhere, usually owing to distribution requirements (Velleman, 1998). In the present study, this phonological process was observed only in words with clusters. Examples: /vjəvəste/→[vəjəte] meaning 'arrangement' /rəŋgo:li/→[gəloti] meaning 'a floral design'	✓	✓	✓
6.	Metathesis The complete interchange of elements from their locations within the adult word (Velleman, 1998) was considered as Metathesis. Examples: /kiʈəki/→[kikəʈi] meaning 'window' /da:ɭimbe/→[ba:linde] meaning 'pomegranate'	✓	✓	--
7.	Consonant harmony This occurred when two non-adjacent consonants within a word become alike or more alike (Velleman, 1998). Assimilation processes are also divided into nasal, labial, velar assimilation and include voicing changes (Bernthal, & Bankson, 1993). This analysis did not include voicing changes and considered all assimilation processes together as consonant harmony. Partial, as well as total consonant harmony was observed in children with DS. It may be noted that nasal, velar and labial assimilation were all taken as examples of consonant harmony. Examples of total consonant harmony: /kiʈəki/→[bəkəki] meaning 'window' Examples of partial consonant harmony: /ku:dəlu/→[ko:gəju] meaning 'hair'	✓	✓	✓
8.	Vowel harmony This occurred when two vowels that are non-adjacent to each other in a word become alike or more alike (Velleman, 1998). Examples: /prəʃne/→[petne] meaning 'question' /i:ruɭɭi/→[u:rulli] meaning 'onion'	✓		

SNo.	Types of phonological processes with examples	DS	MR	TD
9.	Reduplication Repetition of a syllable of a target word that resulted in the creation of a multisyllabic word form (Pena-brooks, & Hegde, 2000) was noted as reduplication. Only total reduplication was considered; repetitions of consonants only were considered as consonant harmony and repetitions of vowels only were categorized as vowel harmony. Examples: /pustəka/→[pəkəkə] meaning 'book' /kənnəɖəka/→[kə:kəkə] meaning 'glasses'	✓	--	--
10.	*Others* These processes include those that have not been traditionally reported in the literature for English and Dutch			
a.	Substitution of geminated clusters for non-geminated clusters This occurred when a non-geminated cluster was replaced by a geminated cluster that comprised one (lengthened) member of the non-geminated cluster or of a sound that was not a member of the original cluster (Rama Devi, 2006). Examples: /kriʃɳa/→[kissa];/driʃja/→[diʃʃa] meaning 'Sight'	✓	✓	✓
b.	Syllable deletion Omission of syllables in any position of the word i.e. initial, medial or final positions was operationally defined as syllable deletion. Omission of only vowels was also considered syllable deletion since vowels serve as syllabic nuclei in Kannada (Rajapurohit, 1975). It may be noted that since stress is not clearly defined in Kannada, the process of'unstressed syllable deletion' was not considered. Instead it was considered more meaningful to discuss this phonological process based on the position in the word. It may also be noted that syllable deletions in medial and final positions were sometimes associated with compensatory processes such as vowel prolongation and gemination, as illustrated in some of the examples below.			
i.	Syllable deletion in initial position Examples: /ʧəmətʃa/→[mətʃa] meaning 'Spoon' /brəm^{h}ərʃi/→[məʃi] meaning 'Sage'	✓	--	--
ii.	Syllable deletion in medial position Examples: /ərəməne/→[ə:mne] meaning 'Palace' /a:lugəɖɖe/→[ə:gədde] meaning 'Potato'	✓	✓	--
iii.	Syllable deletion in final position Examples: /kənnəɖəka/→[ka:təɖə] meaning 'Spectacles' /gaɖija:ra/→[gədəja] meaning 'Clock'	✓	--	--

The different phonological processes that were observed in persons with Down syndrome have also been reported in the literature in English and Dutch speaking, younger (Dodd, 1976; Stoel-Gammon, 1980; Mackay, & Hodson, 1982; Smith, & Stoel-Gammon, 1983; Bleile, & Schwarz, 1984) and older persons with Down syndrome (Van Borsel, 1988; Sommers et al., 1988; Shriberg & Widder, 1990; Van Borsel, 1996). Of these studies, very few have reported vowel errors in persons with Down syndrome.

There are differences in the phonetic and phonotactic structure of Kannada as compared to English and Dutch and hence certain differences in the types of phonological processes were expected. Closed syllables occur very rarely (Hiremath, 1980) in Kannada; therefore, the frequency of phonological processes such as final consonant deletion was limited. Vowels are generally described in Kannada on the basis of length as short and long vowels (Nayak, 1967; Upadhyaya, 1972) because the difference in duration is around 1:1.8-2.3 (Rajapurohit, 1975). Vowels are not classified as tense and lax because formant frequencies are essentially the same for short and long counterparts (Sreedevi, 2000). Hence terms such as vowel shortening and vowel prolongation were considered better descriptors than vowel tensing and laxing. Clusters in Kannada's vernacular form are present mostly in the medial position both as two-sound and three sound clusters. A few initial clusters are present (Nayak, 1967), but final clusters have only been reported in borrowed English words in Kannada with a limited frequency of occurrence (Rupela & Manjula, 2006). Both identical (geminated) and non-identical (non-geminated) clusters are found in the word medial position (Hiremath, 1980). Medial geminates are the most frequently observed clusters and are acquired as early as 12-18 months of age (Rupela & Manjula, 2006). Colloquially, disyllabic words are most common (Hiremath, 1980), but words containing 1-6 syllables are also possible (Nayak, 1967). Final consonants rarely occur in Kannada except in borrowed English words, so open disyllables are the most commonly found word shapes, followed by trisyllables and multisyllables (Rupela & Manjula, 2006).

Another difference was that stress is not clearly defined in Kannada, hence instead of defining syllable deletions in terms of stress (unstressed syllable deletion), they were defined in terms of position i.e. as initial, medial and final syllable deletions. Kannada also comprises a large number of words with geminated clusters in the medial position of words (Hiremath, 1980). Geminates are acquired as early as 12 months in Kannada speaking children (Rupela & Manjula, 2006). Such reports of early acquisition of geminates are also present in Telugu (Neethi Priya, 2007), Japanese (Aoyama, 1999) and Finnish-speaking (Vihman & Velleman, 2000; Kunnari, Nakai, & Vihman, 2001; Kunnari, & Savinainen-Makkonen, 2007) typically developing children. Lastly, retroflex consonants are an important part of the Kannada phonetic repertoire. They are produced when the tip of the tongue is curled back and made to touch the hard palate (Upadhyaya, 1972). Fronting of retroflex stops, and fronting of /ɳ/ and /ɭ/ were also frequently observed in the participants.

Rama Devi (2006) studied thirty typically developing Kannada-learning children and thirty Kannada speakers with hearing impairment in the age range of five to nine years. The most commonly occurring phonological processes in terms of frequencies of occurrence (no. of persons that exhibited a particular phonological process) were deaspiration and 'h' deletion. These phonological processes are considered dialectal variations by some investigators (Mallikarjun, 1974). Other commonly occurring processes reported by Rama Devi (2006) in typically developing children were cluster reduction and fronting of retroflexes.

A few phonological processes were not observed in typically developing children (MA matched) in this study. They are fronting of velars, backing of bilabial and dental stops, vowel prolongation, shortening, lowering, monophthongization or diphthong reduction, palatalization of alveolar fricative *Is/,* consonant deletions in initial and medial positions and metathesis. The phonological processes that were noticed only in children with Down syndrome are fronting of dental stops to bilabial stops, vowel decentralization, raising, harmony, denasalization of nasal continuants, reduplication and syllable deletion in initial and medial positions.

b. Percentage occurrences of phonological processes

Errors in speech were tabulated as phonological processes and their percentage occurrences were computed. All phonological process errors were divided into space, timing and whole word errors. To calculate the percentage occurrences of phonological processes, opportunities of occurrence of errors i.e. potential numbers of occurrences per phonological process were first tabulated. Except for the process of monophthongization that had only one possibility of occurrence, all other processes had a minimum of four opportunities of occurrences. Percentage occurrences of the different processes were calculated by the formula:

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

For example, if the actual numbers of occurrences of the phonological process vowel centralization in one person with Down syndrome was 10 and it had 56 potential occurrences, then the percentage occurrence of the phonological process in that person would be 17.85%. Percentage occurrences were calculated for all participants and comparisons were drawn across the three groups using one-way ANOVA. A significant main effect of groups was found for most of the phonological processes. Table 26a, 26b, and 26c reveal significant differences in terms of percentage occurrences of phonological processes across the three groups for all except backing of bilabial and dental stops, palatalization of alveolar fricative /s/, depalatalization of palatal fricative /J7, affrication of fricatives, prevocalic voicing and metathesis. On careful investigation of some of the processes that did not differ by group, it was evident that the frequencies of occurrence of some of these such as backing of bilabial and dental stops were limited in both groups of participants and no significant differences were observed. For others, such as deaffrication of affricates (to fricatives) and depalatalization of /ʃ/, high standard deviation values could be the reason for reduced differences between the two groups.

Table 26a: Mean percentage occurrences of space errors, SDs and F values.

SNo.	Phonological process	Percentage occurrences of phonological processes						
		Down syndrome (DS)		Mental retardation (without DS)		Typically developing children		One-way ANOVA
		Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
1.	*Fronting*							
a.	Fronting of velars	5.07	7.28	2.38	6.46	0.00	0.00	3.61*
b.	Fronting of retroflex stops	20.60	13.27	3.33	7.35	0.66	1.11	32.29***
c.	Fronting of ɭ and ɳ	23.33	21.05	20.00	17.02	1.53	1.72	8.50***
d.	Fronting of dental stops to bilabial stops	1.73	4.65	0.00	0.00	0.00	0.00	3.12*
2.	*Backing*							
a	Backing of bilabial stops	1.04	1 2.36	0.20	1.14	0.00	0.00	2.71
b	Backing of dental stops	3.21	4.72	2.14	5.97	0.00	0.00	2.21
3.	*Vowel deviations*							
a.	Vowel centralization	4.52	5.171	0.35	0.72	0.13	0.35	14.71***
b.	Vowel prolongation	2.61	2.9	2.02	4.19	0.00	0.00	15.09***
c.	Vowel shortening	6.11	0.10	1.85	1.01	0.00	0.00	7.40***
d.	Vowel raising	0.82	1.75	0.00	0.00	0.00	0.00	4.90**
e.	Vowel lowering	1.42	2.21	0.11	0.45	0.00	0.00	7.96***
f.	Monophthongization or diphthong reduction	50.00	50.85	13.33	34.57	0.00	0.00	10.57***
g	Vowel decentralization	2.32	3.28	0.00	0.00	0.00	0.00	11.14***
4.	Palatalization of alveolar fricative /s/	0.37	2.02	0.37	2.02	0.00	0.00	0.24
5.	Depalatalization of palatal fricative /ʃ/	22.00	27.46	10.00	17.22	9.33	12.79	2.95

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

Table 26b: Means of percentage occurrences of timing errors, SDs and F values.

SNo.	Phonological process	Percentage occurrences of phonological processes						
		Down syndrome (DS)		Mental retardation (without DS)		Typically developing children		One-way ANOVA
		Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
1.	Gliding of laterals (/r/, /l/) and fricative /s/	3.83	5.78	0.50	2.01	0.60	2.34	6.04***
2.	Stopping	4.16	5.01	1.38	3.56	0.41	0.86	5.93***
3.	Deaffrication of affricates (to fricatives)	8.88	17.90	1.66	9.12	0.00	0.00	3.43*
4.	Affrication of fricatives	1.11	3.53	0.44	1.69	0.88	2.34	0.46
5.	Denasalization of nasal continuants	5.39	8.07	0.00	0.00	0.00	0.00	997***
6.	Postvocalic devoicing	3.51	5.35	0.18	1.01	0.00	0.00	8.67***
7.	Prevocalic voicing	2.22	5.34	0.22	1.21	0.44	1.72	2.65
8.	*Others*							
a.	Substitution of singleton consonants for geminated clusters (degemination)	15.33	13.57	4.33	6.78	1.73	3.60	13.26***
b.	Substitution of geminated clusters for singleton consonants (gemination)	3.33	3.48	0.27	0.90	3.70	3.95	17.13***

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

Table 26c: Means of percentage occurrences of whole word errors, SDs and F values.

SNo.	Phonological process	Percentage occurrences of phonological processes						
		Down syndrome (DS)		Mental retardation (without DS)		Typically developing children		One-way ANOVA
		Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)_
1.	Consonant cluster reduction	48.02	13.90	21.97	14.81	10.37	6.59	49 94***
2.	*Consonant deletion*							
a.	Initial consonant deletion	11.20	14.70	9.26	0.50	0.00	0.00	12.81***
b.	Consonant deletion in medial position	3.37	4.76	0.26	0.52	0.00	0.00	10.00***
3.	Epenthesis	3.58	5.11	0.83	1.77	0.16	0.64	6.87***
4.	Epenthesis in clusters only	3.95	6.29	0.74	2.04	0.49	1.30	544***
5.	Migration	3.41	4.17	1.16	2.15	1.16	1.59	4.85
6.	Metathesis	0.50	1.01	0.25	0.76	0.00	0.00	2.01***
7.	Consonant harmony	3.53	3.55	0.69	0.95	1.7	3.60	16.04***
8.	Vowel harmony	1.73	1.59	0.00	0.00	0.00	0.00	26.35***
9.	Reduplication	0.66	1.24	0.00	0.00	0.00	0.00	6.44***
10.	*Others*							
a.	Substitution of geminated clusters for non-geminated clusters	12.59	7.93	5.06	7.11	3.70	3.95	11.94***
b.	Syllable deletion							
I.	Syllable deletion in initial position	5.16	8.58	0.00	0.00	0.00	0.00	8.09***
ii.	Syllable deletion in medial position	15.85	12.53	1.17	2.42	0.00	0.00	31.27***
iii.	Syllable deletion in final position	2.25	4.65	0.00	0.00	0.00	0.00	5.21***

*** $p < .001$

Other inferences that could be drawn from Duncan's post-hoc test in terms of differences across the groups are as follows:

- Persons with Down syndrome significantly differed from the two control groups for most of the processes. The two control groups did not differ from each other significantly in terms of (a) space errors such as all vowel deviations, velar fronting, and retroflex fronting, (b) timing errors such as gliding, stopping, degemination, gemination, denasalization, and devoicing, and (c) whole word errors such as consonant deletions in initial and medial positions, syllable deletions in initial, medial and final positions, epenthesis in any position of the word and in clusters, vowel harmony, reduplication, and migration. Dodd (1976) also observed that children with MR (without DS) and the TD group performed similarly when compared to the DS group that performed poorly.
- Different results were obtained for cluster reduction where all three groups differed significantly from one another. Children with Down syndrome exhibited the maximum numbers of errors followed by persons with mental retardation (without DS) and then typically developing children that showed the least percentage of errors. Non-geminated clusters are generally acquired later in Kannada speaking children and by the age of 4 years, they are predominantly occurring (Rupela & Manjula, 2006) even though some errors continue to exist (Rama Devi, 2006).
- The TD and DS groups differed significantly from each other for two processes of deaffrication and backing of dental stops. They did not differ from the group with MR (without DS). These processes occurred relatively

rarely in the participants of this study and that could be the reason for the observation of a deviant pattern compared to the other phonological processes.

- Both groups with disorders did not differ from each other significantly for fronting of /ɭ/ and /ɳ/, but they differed from the typically developing group. Typically developing children did not make as many fronting errors as the two groups with disorders. These retroflex sounds were substituted by their alveolar counterparts /l/ and /*n*/. Retroflex sounds are generally acquired later in Kannada speaking typically developing children (Shyamala, & Basanti, 2003).

Hence, in terms of percentages of occurrences of the various phonological processes, persons with Down syndrome exhibited significant differences when compared to the two control groups for most phonological processes. Persons with Down syndrome exhibited greater percentage occurrences of phonological processes for example, cluster reduction, stopping, gliding, consonant harmony, reduplication, post-vocalic devoicing, deaffrication, fronting, and vowel processes such as vowel lowering, and raising. There were also certain phonological processes that were present only in the group with Down syndrome and not observed in the control groups. Furthermore, certain other processes were present due to differences of Kannada from English/Dutch in terms of its phonetic and phonotactic repertoire. They were gemination, degemination, fronting of retroflex stops, deletions of syllables based on position (initial, medial and final), and vowel processes such as vowel shortening and prolongation.

More numbers of whole word errors were observed in persons with Down syndrome followed by space and timing errors. On the other hand, the two control groups exhibited mostly space errors followed by whole word and timing errors. Children with CAS exhibit more timing and whole word errors when compared to space errors (Velleman, 2003). Hence, praxis breakdown in terms of exhibiting greater whole word and timing errors when compared to space errors is evident in persons with Down syndrome. Vowel errors were also more distinctly exhibited by persons with Down syndrome. As is evident in table 26a, persons with Down syndrome produced many different vowel substitution processes. On the other hand, only one vowel substitution process, namely vowel centralization was observed in the two control groups.

c. Frequency of persons exhibiting various phonological processes

In order to calculate the frequency i.e. number of people that exhibited a particular process, percentages of occurrences of each process were calculated per child in all three groups of participants as follows:

$$\frac{\textit{No. of persons that used the process}}{\textit{Total number of persons in the group}} \times 100$$

In order to compare the frequency of use of the phonological processes, participants from the three groups were compared using statistical analysis, namely 'Uncorrelated equality of proportions'. In table 27, T represents mental retardation (without DS), '2' represents persons with Down syndrome and '3' represents typically developing children (mental age matched). Also in the table, - indicates that values of two groups are equal, and hence no test is required.

Table 27a: Uncorrelated equality of proportions comparing frequencies of phonological processes in terms of space errors used by the three groups of participants

Sno.	Phonological processes	z12	z13	z23
	/. Space errors			
1.	*Fronting*			
a.	Fronting of velars	2.14*	2.04*	3.35*
b.	Fronting of retroflex stops	5.45*	0.98	3.95*
c.	Fronting of /ɭ/ and /ɳ/	0	1.1	1.1
d.	Fronting of dental strops to bilabial stops	2.34*	-	1.68
2.	*Backing*			
a	Backing of bilabial stops	1.72	0.72	1.68
b	Backing of dental stops	2.44*	1.86	3.35*
5.	*Vowel deviations*			
a.	Vowel centralization	6.32*	1.48	4.27*
b.	Vowel prolongation	4.14*	1.86	4.64*
c.	Vowel shortening	3.66*	0.72	3.02*
d.	Vowel raising	3.25*	-	2.37*
e.	Vowel lowering	3.28*	1.02	3.02*
f.	Monophthongization or diphthong reduction	3.05*	1.48	3.35*
g.	Vowel decentralization	4.47*	-	3.35*
4.	Palatalization of alveolar fricative /s/	0	0.72	0.72
5.	Depalatalization of palatal fricative /ʃ/	2.34*	0.67	1.27

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

Table 27a: Uncorrelated equality of proportions comparing frequencies of phonological processes in terms of timing and whole word errors used by the three groups of participants

Sno.	Phonological processes	z12	z13	z23
	//. Timing errors			
1.	Gliding of laterals (/r/, /l/)	3.28*	0	2.5*
2.	Stopping	0.56	0.49	0.93
3.	Deaffrication of affricates (to fricatives)	2.77*	0.72	2.37*
4.	Affrication of fricatives	0.47	0.74	0.34
5.	Denasalization of nasal continuants	4.07*	-	3.02*
6.	Postvocalic devoicing	3.23	0.72	2.7*
7.	Prevocalic voicing	2.28	0.51	1.38
8.	*Others*			
a.	Substitution of singleton consonants for geminated clusters (degemination)	3.11*	0.93	3.39*
b.	Substitution of geminated clusters for singleton consonants (gemination)	3.11*	2.54*	4.64*
	///. Whole word errors			
1.	Consonant cluster reduction	1.78	0.37	1.43
2.	*Consonant deletion*			
a.	Initial consonant deletion	5.58*	0.72	4.64*
b.	Consonant deletion in medial position	4.65*	1.86	5.07*
3.	Epenthesis	2.44*	1.16	2.86*
4.	Epenthesis in clusters only	3.05*	0	2.39*
5.	Migration	2.84*	0.23	2.12*
6.	Metathesis	1.08	1.27	1.86
7.	Consonant harmony	3.83*	1.54	4.70*
8.	Vowel harmony	5.48*	-	4.24*
9.	Reduplication	3.25*	-	2.37*
10.	*Others*			
a.	Substitution of geminated clusters for non-geminated clusters	2.44*	0.22	2.37*
b.	Syllable deletion			
i.	Syllable deletion in initial position	5.27*	-	4.05*
ii.	Syllable deletion in medial position	4.98*	2.21*	5.81*
iii.	Syllable deletion in final position	3.67*	-	2.7*

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

The column zl2 in Table 27 depicts differences between persons with DS and those with mental retardation (without DS). The two groups exhibited significant differences in terms of frequency of occurrences for all processes except for fronting of /ɭ/ and /ɳ/, backing of bilabials, palatalization, stopping, affrication, cluster reduction, and metathesis. Column zl3 indicates comparison of children with DS and typically developing children. The same processes that were observed to be significantly different in terms of frequency in persons with DS and those with mental retardation (without DS) were observed in this comparison as well. However, comparison of frequency of use of phonological processes between persons with DS and typically developing children also revealed differences in terms of backing of dental stops, depalatalization, and voicing. A careful examination of percentages in terms of frequencies revealed that these differences are evident due to the lesser numbers of persons (15) in the typically developing group. The two control groups did not differ from each other except for three processes-Fronting of velars, gemination, and syllable deletion in medial position. The results imply that while the two control groups did not differ from each other except for a few processes, the group with Down syndrome generally exhibited significantly higher frequency of use of phonological processes when compared to the two other groups.

Space errors were observed more commonly in persons with Down syndrome when compared to the two control groups, viz. persons with mental retardation (without DS) and mental age matched typically developing children. Figure 18 depicts the frequencies of persons exhibiting the different space errors.

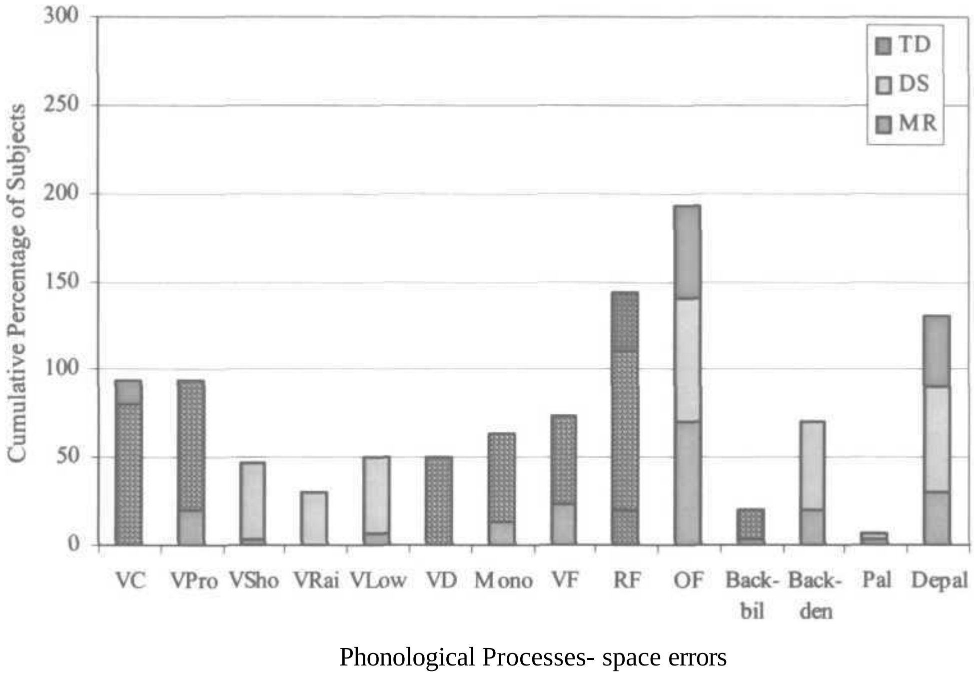

Figure 18: Frequencies of persons exhibiting space errors from three groups of participants

VC- Vowel centralization	RF- Fronting of retroflexes
Vpro-Vowel Prolongation	OF-Fronting of /ɭ/ and /ɳ/
Vsho- Vowel shortening	Back-Bil- Backing of Bilabials
Vlow-Vowel Lowering	Back-Dent-Backing of dentals
Mono-Monophthongization	Pal-Palatalization
VD-Vowel Decentralization	Depal-Depalatalization
VF-Velar Fronting	

Note: Patterns in graph show that majority (> 50%) of the subjects exhibit the particular phonological process

As is evident in figure 18, certain phonological processes occurred in greater than 50% of individuals with Down syndrome. They are, vowel errors such as vowel centralization, prolongation, decentralization, monophthongization, and others such as velar fronting, and backing of bilabials. Fronting of retroflex sounds was observed in greater than 50% amongst all three groups of participants. The only vowel error observed in typically developing children was vowel centralization. Very low frequencies of persons with mental retardation (without DS) exhibited vowel errors such as vowel shortening, and vowel lowering and other space errors such as backing and palatalization. Timing errors were also more frequently observed in persons with Down syndrome when compared to the control groups. Figure 19 depicts the frequencies of persons from the three groups of participants that exhibit the different phonological processes in terms of timing errors.

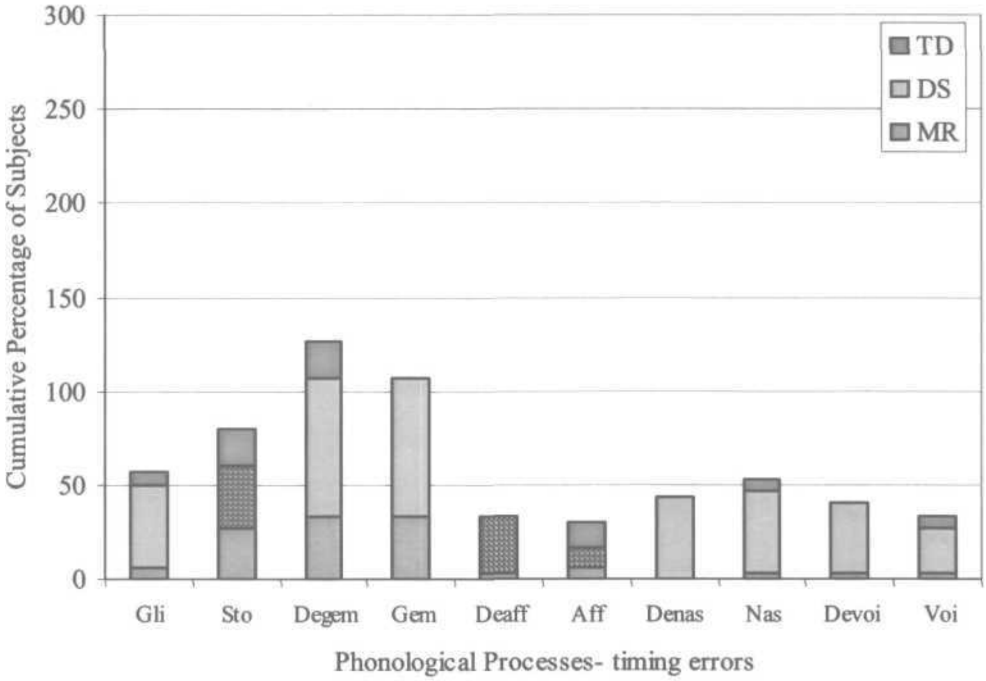

Figure 19: Frequencies of persons exhibiting timing errors from three groups of participants.

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

Note: Patterns in graph show that majority (≥ 50%) of the subjects exhibit the particular phonological process

Figure 19 reveals that greater than 50% of the persons with Down syndrome exhibited phonological processes such as stopping, deaffrication, and affrication. None of the timing errors were exhibited by greater than 50% of the participants from the control groups. None of the typically developing children exhibited denasalization, nasalization, and germination. Very low frequencies of persons with mental retardation exhibited gliding, deaffrication, affrication, postvocalic devoicing, prevocalic voicing, and nasalization.

Figure 20 depicts the frequencies of persons exhibiting different phonological processes in terms of whole word errors from the three groups of participants. Greater numbers of persons with Down syndrome exhibited the different whole word errors when compared to the control groups. More than 50% of persons with Down syndrome exhibited phonological processes such as, initial consonant deletion, consonant deletion in the medial position, epenthesis, epenthesis in clusters, and migration. Certain phonological processes were observed in greater than 50% of all three groups of participants such as, consonant cluster reduction, and substitution of geminated for non-geminated clusters. These have been depicted by the patterns on the bar graphs in figure 20.

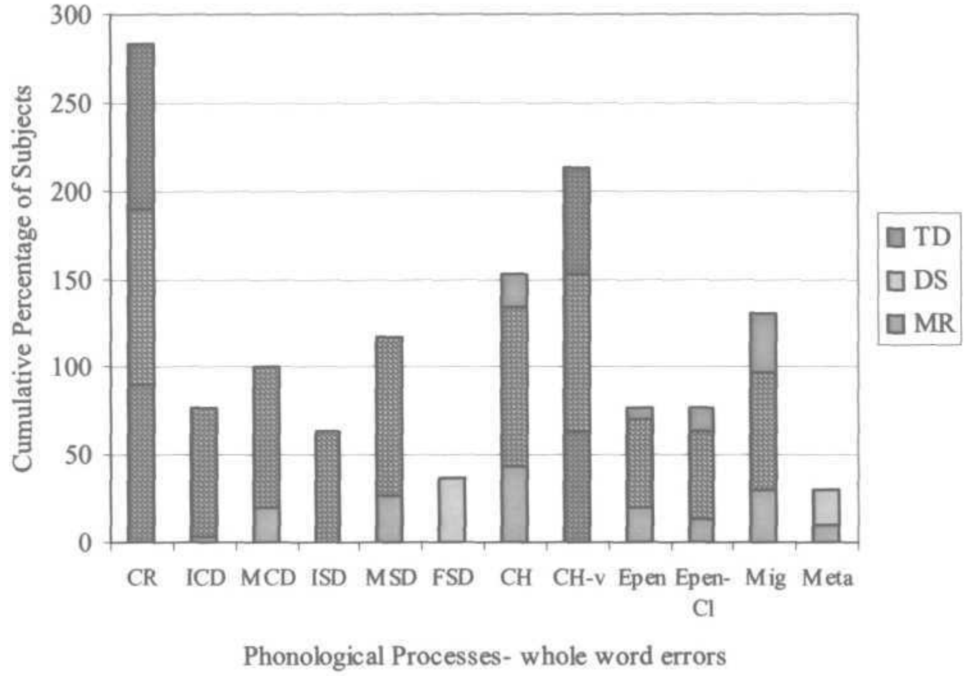

Figure 20: Frequencies of persons exhibiting whole word errors in all three groups of participants

CR-Cluster Reduction	CH- Consonant Harmony
ICD- Initial Consonant Deletion	Epen- Epenthesis
MCD- Medial Consonant Deletion	Epen-cl-Epenthesis in clusters
ISD- Initial Syllable Deletion	Mig- Migration
MSD- Medial Syllable Deletion	Meta-Metathesis
FSD- Final Syllable Deletion	

CH-v- Substitution of geminate clusters for non-geminate clusters
Note: Patterns in graph show that majority ($\geq$ 50%) of the subjects exhibit the particular phonological process

As is evident from figure 20, none of the typically developing children exhibited consonant deletion or syllable deletion phonological processes and very low frequencies of persons with mental retardation (without DS) exhibited phonological processes such as initial consonant deletion, consonant deletion in the medial position, and none of them exhibited final syllable deletion. While a higher frequency of persons with Down syndrome exhibited migration, they exhibited metathesis with a lower frequency. Statistically significant differences were observed between persons with Down syndrome and the control groups in terms of frequencies of persons exhibiting the phonological processes. Certain phonological processes such as vowel errors, velar fronting, backing of bilabials, (space errors); stopping, deaffrication, affrication (timing errors); and initial consonant deletion, consonant deletion in the medial position, epenthesis (whole word errors) were observed in greater than 50% of persons with Down syndrome.

Persons with Down syndrome exhibited more phonological processes both in terms of percentage occurrence and frequencies of individuals the processes were observed in. Significant differences were observed between the experimental group and the two control groups for most of the phonological processes. In general, the group with Down syndrome was quite heterogeneous in terms of occurrence of phonological processes, as is evident from some of the standard deviation values in table 26c. Certain processes were suggestive of verbal praxis deficits or CAS in persons with Down syndrome such as greater omissions, vowel deviations etc. which will be discussed in greater detail in the following section.

2. Aspects that suggest presence of verbal praxis deficits

Comparison of phonological processes across the three groups of participants revealed significant differences between the experimental group and control groups in terms of percentage occurrences of phonological processes and frequency of persons that exhibited the phonological processes. However, it is important to look for errors that specifically describe verbal praxis deficits in persons with Down syndrome. This part of the presentation deals with phonological errors suggestive of verbal praxis deficits. The characteristic features that emerged in the experimental group render definite support to the observation of poor praxis control and praxis deficits in this group. Some of the phonological characteristics in Childhood Apraxia of Speech that are being dealt with in this section of verbal praxis deficits in persons with Down syndrome are:

- High rate of consonant omissions and substitutions (Crary, 1984b; Hall et al., 1993; Forrest & Morrisette, 1999; Nijland et al., 2002; Nijland, et al., 2003; Lewis et al., 2004)
- Difficulties sequencing phonemes and syllables, including metathetic errors (Hall et al., 1993; Nijland, et al., 2002; Lewis et al., 2004)
- Unusual errors (Stackhouse, 1992; Hall et al., 1993; Velleman & Strand, 1994; Davis et al., 1998; Forrest, 2003; Lewis et al., 2004)
- Vowel errors (Pollock & Hall, 1991; Hall et al., 1993; Walton & Pollock, 1993; Shriberg et al., 1997a, 1997b; Davis et al., 1998; Forrest & Morrisette, 1999; Nijland etal., 2003)
- Assimilatory errors or contextual substitution errors including voicing errors (Hall et al., 1993; Forrest & Morrisette, 1999; Nijland et al., 2003)
- Increased nasality (Hall, et al., 1990; Shriberg et al., 1997a, 1997b; Shriberg, et al., 2003)

Some of these verbal praxis deficits are present in persons with Down syndrome to a greater extent when compared to the control groups and they are elaborated as follows:

i. High degree of omissions

These errors they indicate fundamental difficulties in planning the whole word (Velleman, 2003), and in other words difficulties in verbal praxis skills. They are depicted in figure 21.

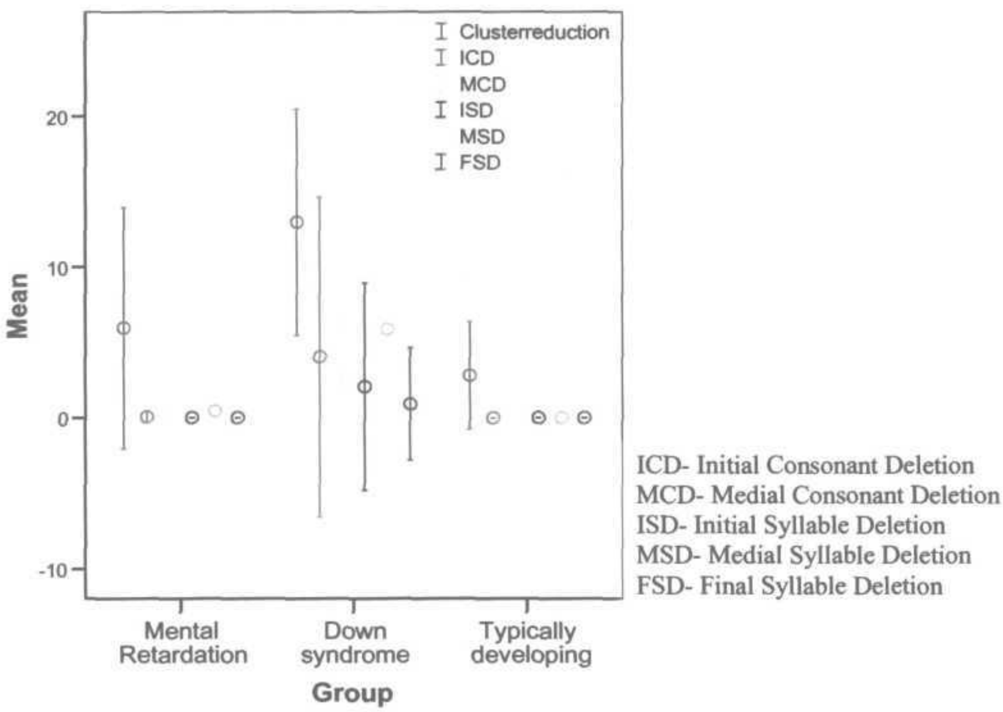

Figure 21: Omission errors at word level in the three groups of participants

Statistically significant differences as depicted in Table 26c were observed between the three groups with more numbers of omission errors in the group with Down syndrome. Omission errors included (a) consonant deletions in initial, and medial positions, (b) cluster reduction, and (c) syllable deletions at initial, medial and final positions. These errors have been reported in English-speaking and Dutch speaking persons with Down syndrome as well (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon, 1983; Sommers et al., 1988; Van Borsel, 1988, 1996; Stoel-Gammon, 1997,2001).

Additionally, as described in the earlier section, it was also noticed that omissions were often related to vowel prolongation and gemination that serve to increase the syllable length. So these phonological processes were presumably exhibited as a means of compensation for the syllable deletion. For example, when the medial syllable /ʈə/ was deleted in the word /kiʈəki/ meaning 'window', it was geminated and [kitti] was produced instead. An example for the association of vowel prolongation and syllable deletion is when /ʧə/ in the word ,/ʧəmətʃə/ (meaning 'spoon') was deleted, vowel prolongation of the next syllable /mə/ occurred to produce [mə:tʃə]. Such associations have not been reported previously in children with Down syndrome. Errors of omission with or without compensation of length are suggestive of praxis deficits.

ii. Presence of vowel deviations

Children with DS exhibited significantly higher numbers of vowel deviations such as, vowel centralization, vowel prolongation, vowel shortening, vowel raising, and monophthongization. An unusual process of vowel decentralization was also noted in persons with Down syndrome where the schwa vowel was substituted by a higher and/or front vowel. In the two control groups except for vowel centralization, other vowel errors were rarely observed and, there were no instances of vowel decentralization and vowel raising in the control groups. The errors are depicted in figure 22.

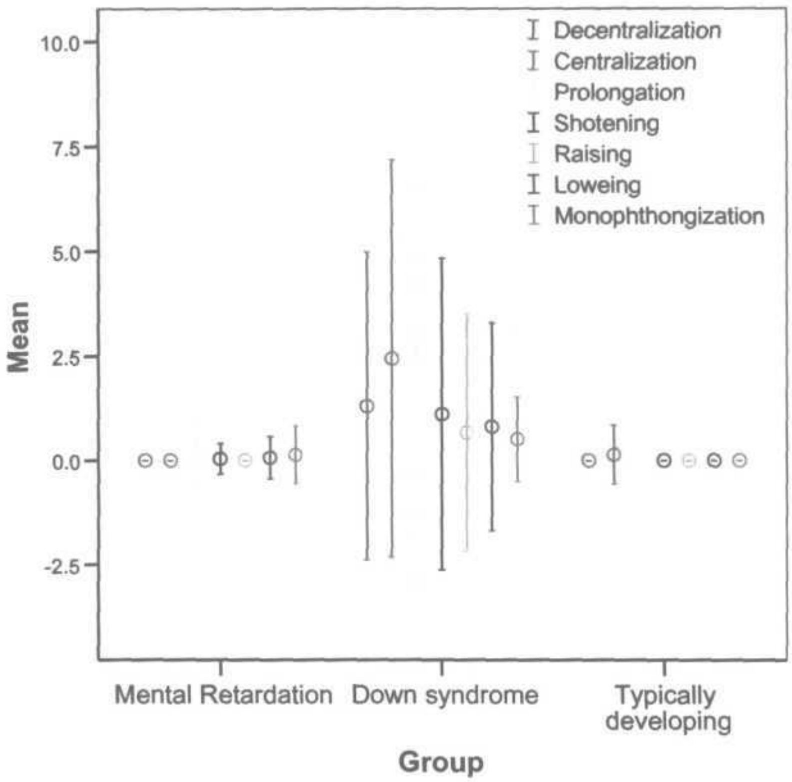

Figure 22: Vowel errors observed at word level in three groups of participants.

Table 26a shows the comparisons of vowel errors in terms percentage occurrences across the three groups of participants. These errors are suggestive of difficulties in planning of the articulatory space that is a characteristic error observed in persons with praxis deficits. Studies on vowel errors amongst persons with Down syndrome are few. Van Borsel (1996) analyzed vowel errors in terms of additions, omissions and substitutions in adolescents and adults with DS in the age range of 15;4 to 28;3 years.

Omissions and additions were considered separately in the study, and substitutions were not found to be significantly different from the 2;6 to 3;4 year old typically developing group. However, the present study indicated significant differences between persons with Down syndrome and the control groups in terms of vowel substitutions. This could have been because of the different age groups of comparisons in the present study and the Van Borsel (1996) study.

iii. Presence of voicing errors

Voicing errors have frequently been reported as assimilatory processes in persons with CAS (Hall et al., 1993; Forrest & Morrisette, 1999; Nijland et al., 2003). These assimilatory processes occur as a result of the inability to sequence syllables adequately and inability to plan the voicing of utterances appropriately. These are suggestive of deficits in the timing domain of planning of speech sounds. Difficulty in producing and maintaining appropriate voicing during speech has been reported frequently in persons with Down syndrome (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon, 1983; Bleile & Schwarz, 1984; Van Borsel, 1988, 1996; Stoel-Gammon, 1997, 2001; Kumin & Adams, 2000). In this study, significant differences were found for postvocalic devoicing but not for prevocalic voicing errors across the three groups of participants. Persons with Down syndrome exhibited more numbers of errors when compared to the two control groups.

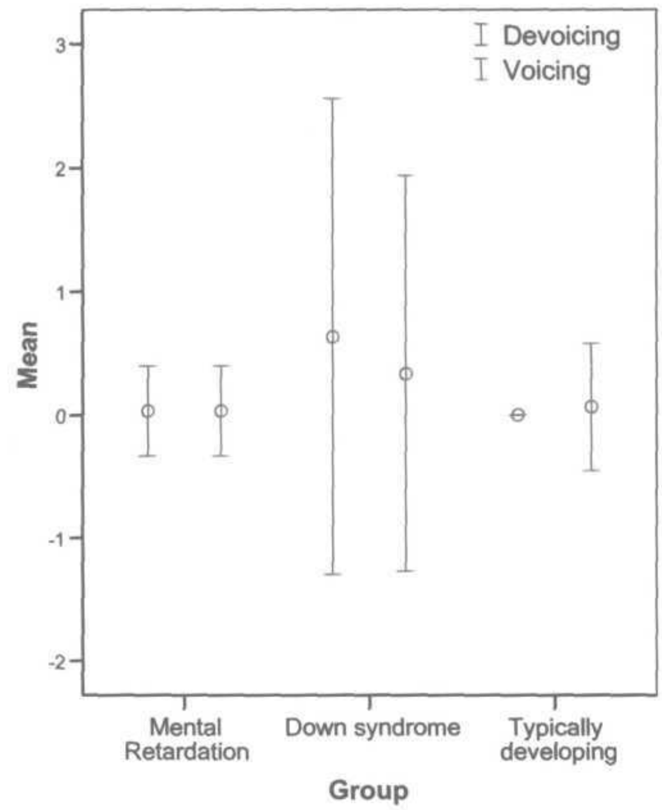

Figure 23: Voicing errors observed at word level in the three groups of participants

iv. *Difficulty in sequencing phonemes and syllables*

Problems in correctly sequencing a speech utterance are central to the disorder of apraxia (Hall et al., 1993) and these errors have also been reported in persons with Down syndrome (Rosin et al., 1988; Kumin et al., 1994; Kumin, 1994; Kumin & Adams, 2000). Errors of addition have also been observed by Dodd (1976) as idiosyncratic errors. Shriberg and Widder (1990) and Hamilton (1993) observed errors of addition in American-English and English-speaking adults with Down syndrome, Van Borsel (1988,1996) observed these errors in Dutch speaking adults. Errors of migration (66.7%

of children with DS) were observed more often than metathesis (20%) in individuals with Down syndrome. Metathesis has been reported to occur in persons with Down syndrome (Dodd, 1976; Stoel-Gammon, 1980; Van Borsel, 1988; Kumin & Adams, 2000) but as an uncommon error type (Van Borsel, 1996).

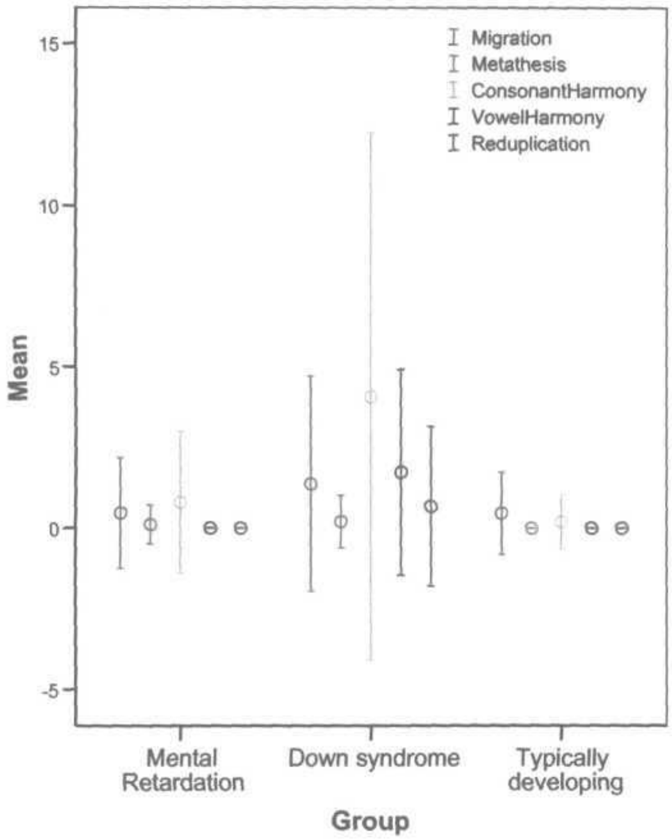

Figure 24: Sequencing errors at word level observed in the three groups of participants

Significant differences between the experimental group and control groups were evidenced for all processes except for metathesis. Processes of assimilation or hannony (consonant and vowel hannony) and reduplication that have been reported in Down syndrome (Dodd, 1976; Stoel-Gammon, 1980; Bleile & Schwarz, 1984; Van Borsel, 1988; Kumin & Adams, 2000) were also observed in this study in persons with Down syndrome in significantly higher occurrence than the other two groups.

Consonant clusters are reported to be more difficult to produce than singleton consonants (Morley, 1959). While cluster reduction was a commonly observed process in all three groups of participants, significant differences were observed across these groups. Persons with Down syndrome produced significantly higher numbers of cluster reduction errors than persons with mental retardation (without DS) who in turn produced more numbers of errors than the typically developing group. This process has been reported in English-speaking and Dutch-speaking persons in Down syndrome as well (Dodd, 1976; Stoel-Gammon, 1980; Mackay & Hodson, 1982; Smith & Stoel-Gammon; 1983; Bleile & Schwarz, 1984; Van Borsel, 1988, 1996; Sommers et al., 1988; Hamilton, 1993; Stoel-Gammon, 1997, 2001). Another type of cluster reduction that was observed in all three groups of children but more frequently observed in persons with Down syndrome was substitution of geminated clusters for non-geminated clusters. This error has not been reported in the literature because most of the research in persons with Down syndrome has been carried out in Dutch or English that are highly similar Germanic cognate languages. Kannada comprises a large number of words with geminated clusters in the medial position of words (Hiremath, 1980). Geminates are acquired as early as 12 months in Kannada speaking children (Rupela & Manjula, 2006). Such reports of early acquisition of geminates are also present in Telugu (Neethi Priya, 2007), Japanese

(Aoyama, 1998) and Finnish-speaking (Vihman & Velleman, 2000, Kunnari et al, 2001; Kunnari & Savinainen-Makkonen, 2007) typically developing children.

v. *Presence of atypical or idiosyncratic errors*

'Unusual' or 'atypical' phonological patterns or idiosyncratic errors differ from the more common phonological processes and are seen in both typically developing children and those with phonological disorders (Bernthal & Bankson, 1993). They are those that are not typical of normal development (Edwards & Shriberg, 1983; Stoel-Gammon, & Dunn, 1985). For example, errors such as vowel errors, addition errors, and high variability are included as atypical errors observed in persons with CAS (Davis et al., 1998; Nijland et al., 2002; Lewis et al., 2004). Idiosyncrasies in the speech are considered as indications of deviance in coarticulation patterns in persons with CAS by investigators (Boers, Maassen, & van der Meulen, 1998; Nijland et al., 2002). Errors that fell into regular patterns in terms of preferences for certain sounds have already been discussed. The present section only incorporates substitution processes that are not accounted for in most phonological process analyses. The presence of such errors in persons with Down syndrome has been reported in the literature (Dodd, 1976; Stoel-Gammon, 1997, 2001). The errors that were noticed in persons with Down syndrome in this study are listed as follows:

Examples for substitution of nasal consonants:

- /m/→[j] /brəmərʃi/→[bəjəsi] meaning 'Sage'

- /m/→[j] /əḍigemane/→[e:jane] meaning 'Kitchen'
- /m/→[w] /ʧəməʧa/→[ʧəwəʧa] meaning 'Spoon'
- /n/→[ʧ] /kənnəḍəka/→[biʧeka] meaning 'Spectacles'

Examples for substitution of stops:

- /k/—>[ḷ] /kənnəḍəka/→[ka:təḷa] meaning 'Spectacles'
- /g/—>[w],/ba:gilu/→[ba:wəllu] meaning 'Door'
- /t/—>[n] /teŋginəka:ji/→[neɾeka:ji] meaning 'Coconut'
- /ḍ/→[l] /gəḍija:ra/→[gələja] meaning 'Clock'
- /ḍ/→[ɾ] /huḍugi/→[huɾəgi] meaning 'Girl'
- *Pol*—»-[w] /ba:ḷehəṇṇu/→[wa:leənnu] meaning 'Banana'

Examples for substitution of affricates:

- /ʧ/→[k] /swəʧʧʰa/→[wokka] meaning 'Clean'
- /j/→[n] /gəḍija:ra/→[gəna:ra] meaning 'Clock'

Examples for substitution of/l/, /r/, and /ḷ/:

- /l/→ [nd] /a:lugəḍḍe/→[andəgəḍḍe] meaning 'Potato'
- /l/→[ɻ] /təle/→[ta:ɻe] meaning 'Head'
- /r/→[ɻ] /i:ruḷḷi/→[ɻu:li] meaning 'Onion'

- /ɭ/→[ɾ] /ga:ɭipəʈa/→[ga:ɾəpətta] meaning 'Kite'
- /ɭ/→[n] /da:ɭimbe/→[da:nəbe] meaning 'Pomegranate'

Comparisons were done in terms of total numbers of idiosyncratic errors observed in the different participant groups. In contrast with the two control groups i.e. mental retardation (without DS) and typically developing children, participants with DS exhibited more idiosyncratic errors of different types. Statistically significant differences were obtained using one-way ANOVA with an 'F' value of 5.091 and 'p' value of 0.009. Duncan's post-hoc test revealed that the two control groups did not differ from each other in terms of numbers of atypical errors exhibited by the different groups.

vi. Presence of sound preferences

Typically developing children sometimes have a segment or two that they substitute for a large number of sounds or sound classes in order to avoid the use of certain other sounds in their productions (Bernthal & Bankson, 1993). Often they replace marked sounds with unmarked sound, which they find easiest to produce (Gnanadesikan, 2004). This tendency has been reported in typically developing children during phonological development. In this study, the phenomenon of sound preferences was observed only in the group with Down syndrome and not in the two control groups. Moreover, such preferences in children in the age range of 11;6 to 14;6 years would be considered inappropriate. These errors indicated that the participants were not able to use different speech sounds but were repeatedly using those sounds that were established in their phonetic and phonotactic repertoire. This phenomenon is characteristic of praxis deficits because it suggests deficits in timing of articulators to produce different speech sound (Kent & Rosenbek, 1983). Moreover, use of the same speech sound to substitute for a variety of other speech sounds indicated the difficulties in coordination of different articulators (Ziegler & von Cramman, 1985) to produce the appropriate word. A few examples as observed in persons with Down syndrome are as follows:

Participant DS-21: This child showed a tendency to use the velar sound /k/ or /g/ as substitution for other phonemes.

- /s/→ [k] /se:bu/→[ke:wu] meaning 'Apple'
- /s/→ [k] /si:re/→[ki:e] meaning 'Saree'- a dress
- /ʧ/→ [k] /ʧəməʧa/→[əməka] meaning 'Spoon'
- /n/→ [g] /ərəməne/→[ərəməge] meaning 'Palace'

She also tended to use a combination of velars and bilabials in words, often in an alternating pattern. For example:

- /pustəka/→[pəkəka] meaning 'Book'
- /ga:ɭipəʈa/→[gi:pəka] meaning 'Kite'
- /vəidja/→[baika] meaning 'Doctor'
- /brəm^{h}ərʃi/→[kəməki] meaning 'Sage'

Participant DS-13: This child had a preference towards the use of the glottal */hi*

- /r/→[h] si:re/→[i:he] meaning 'Saree'- a dress

- /b/→[h] /se:bu/→[se:hu] meaning ‘Apple’
- /n/→[h] /pra:rtʰəne/→[pa:təhe] meaning ‘Prayer’

Participant DS-7: This child used a combination of phonemes /ɖ/ or /ɭ/ and /t/ making her speech quite unintelligible. The phonemes /ɖ/ and /ɭ/ are both acquired later in Kannada speaking typically developing children (Shyamala & Basanti, 2003), so it was quite surprising that the child used them. In this case, the child's preference does not seem to be based on ease of production.

- /ərəməne/→[ə:ɖəje] meaning ‘Palace’
- /da:ɭimbe/→[da:ɭətti] meaning ‘Pomegranate’
- /i:ruɭɭi/→[ɔ:ɖuti] meaning ‘Onion’

Participant DS-18: This child substituted most phonemes with /m/.

- /s/→[m] /si:re/→[mi:e] meaning ‘Saree’- a dress
- /b/→[m] /se:bu/→[ba:mu] meaning ‘Apple’
- /g/→[m] /gəɖija:ra/→[məja:ɹa] meaning ‘Clock’
- /ɳ/→[m] /ba:ɭehəɳɳu/→[ba:wemu] meaning ‘Banana’
- /t/→[m] /teŋginəka:ji/→[mentʃika:i] meaning ‘Coconut’

vii. Nasality/nasal emission errors

Nasal quality or hypemasality in the speech of persons with CAS has been reported in the literature (Hall et al., 1993). Others (Yoss & Darley, 1974) have also reported presence of nasal assimilation in children with CAS. Bowman, Parsons and Morris (1984), and Parsons (1984) have observed the presence of nasalization and denasalization errors in children with CAS. Results are presented in figure 25.

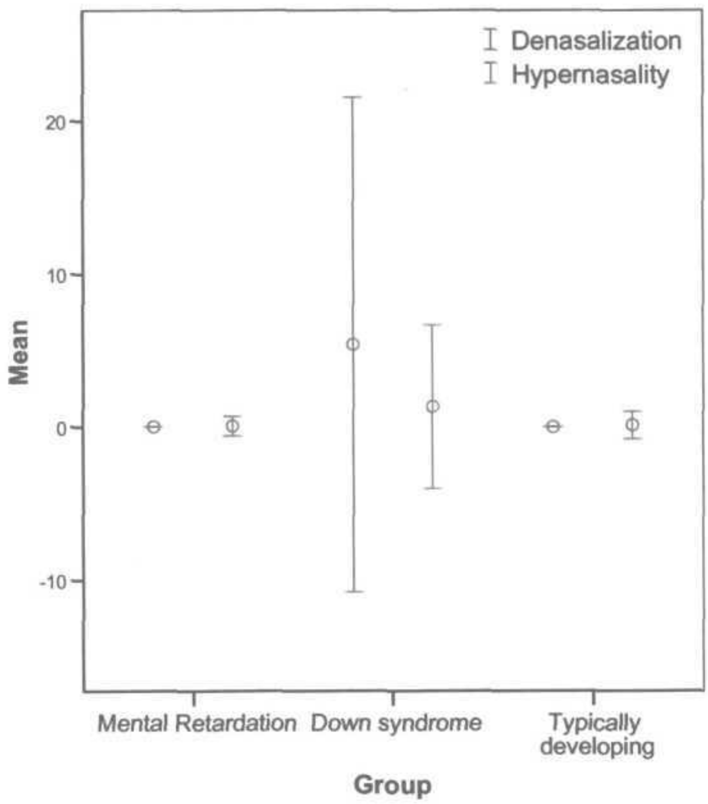

Figure 25: Nasality errors at word level in three groups of participants

This problem has been viewed in the motor control perspective as poor control of the velopharyngeal mechanism (Hall et al., 1993). Trost-Cardamone (1986) noted that the speech programming for velopharyngeal port operation in children with CAS is disturbed, and this problem underlies the oral vs. nasal errors made by some children with CAS. Some investigators also consider hypernasality as a sign of dysarthria in persons with CAS (Velleman, 2003). Errors of 'denasalization' were frequently noted in children with Down syndrome in this study and this was statistically significant from the other groups as depicted in Table 26b. These findings are supported by Shriberg and Widder (1990) and Kumin and Adams (2000) in English-speaking persons with Down syndrome. Hypernasality on vowels was also noticed and the raw data were compared using one-way ANOVA. Statistically significant differences were found between the two control groups and the children with DS with an 'F' value of 5.156 and 'p' value of 0.008.

The task of imitation of words by the three groups of participants indicated various phonological processes that were suggestive of CAS in persons with Down syndrome. Significant differences were observed between the experimental group i.e. persons with Down syndrome and the two control groups. These errors included high degree of omissions, presence of vowel deviations, voicing errors, atypical or idiosyncratic errors, sound preferences, difficulty in sequencing phonemes and syllables, and errors concerning nasality/nasal emission. Significant differences were observed for all these different types of errors indicating that verbal praxis deficits are present in persons with Down syndrome. However, the variability of responses as evident from the high standard deviation values within the group with Down syndrome needs to be kept in mind. Not all persons with Down syndrome exhibited these different types of errors to the same degree. Apart than phonological processes, other errors suggestive of verbal praxis deficits were also noted in persons with Down syndrome.

3. Other errors

Errors other than phonological processes were also observed in persons with Down syndrome. The investigator looked for groping errors and disfluencies in the participants. While groping errors and disfluencies were noted down per word, distortions and weak precision in articulation were noted down per consonant in the words. Segment to segment inter-transcriber reliability was 75.6% and intra-transcriber reliability was 80% for these errors. Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. Table 28 depicts the results.

Table 28: Errors other than phonological processes observed in imitation of words task

SNo.	Other errors	F(2,72)
1.	Groping errors	3.85*
2.	Disfluencies	3.58*
3.	Distortion errors	12.37***
4.	Weak precision in articulation	15.89***

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

a. Presence of groping

Groping or silent posturing of articulators has been cited by many clinicians as a commonly observed behaviour amongst children exhibiting apraxia (Crary, 1984b, 1993; Robin, 1992; Hall et al., 1993; Ozanne, 1995; Shriberg et al., 1997a, 1997c; Forrest, & Morrisette, 1999; Nijland et al., 2002; Forrest, 2003; Nijland et al., 2003; Lewis et al., 2004). In groping, the persons try to look for the right place of articulation in the absence of an adequate plan for the particular utterance uducating poor praxis control. Hall et al., (1993) considered groping and silent posturing as separate entities unlike other investigators that generally consider both together. They defined silent posturing as a static state of articulatory position that occurs without sound production and groping as an active, ongoing series of movements of the articulator in an attempt to find the desired articulatory position necessary for correct phoneme production. In this study, because the incidences of these behaviors were sparse, no attempt was made to further divide them into groping/silent posturing. While this behaviour was observed in 30% of persons with DS, none of the participants in the two other groups exhibited groping. One-way ANOVA revealed significant differences between the three groups as depicted in Table 28.

b. Occurrence of disfluencies

Persons with Down syndrome are frequently reported to have disfluencies or stuttering in conversational speech of persons with Down syndrome (Otto & Yairi, 1974;

Farmer & Brayton, 1979; Van Riper, 1982; Willcox, 1988; Devenney & Silverman, 1990; Preus, 1990; Devenney et al., 1990; Kumin, 1994; Miller & Leddy, 1998). Speech errors such as prolongation, interjections, pauses and repetitions of sounds, syllables, parts of words, and whole words have been reported in persons with Down syndrome. However, in this study, these errors were also noted down in repetition of words. The kinds of errors included inaudible pauses and syllable repetitions that were noted in 40% of children with Down syndrome in this study. Disfluencies were also observed in 10% and 20% of persons with MR (without DS) and TD groups respectively. As is apparent from Table 28, one-way ANOVA revealed significant differences across the three groups. Stuttering has also been associated with CAS because both disorders are said to have common central neurological processing deficits (Byrd & Cooper, 1989). Various reports of stuttering in CAS are present (Aram & Nation, 1982; Hall et al., 1993) and it has even been considered as a CAS error type by others (Rosenbek & Wertz, 1972; Yoss & Darley, 1974). Rosenbek (1980) gave two hypotheses to explain the similarities in symptoms between CAS and stuttering. One explanation was that since CAS disrupts the timing of speech, it might even be one of the causes of stuttering. Another hypothesis was that while CAS may be an insufficient cause of stuttering, the disfluency may result from the attempt to correct articulatory errors.

c. Distortion errors

Distortion errors were observed in 60% of children with Down syndrome in this study. Other studies that support presence of distortion errors in persons with DS are those of Van Borsel (1996), and Shriberg and Widder (1990). Such errors have been observed in persons with CAS (Williams, Ingham, & Rosenthal, 1981) and have also been considered important characteristics in diagnosing the disorder (Shriberg et al., 1997a, 1997b). Statistical analysis using one-way ANOVA revealed significant differences across the three groups as depicted in Table 28. The group with Down syndrome exhibited significantly higher numbers of distortion errors when compared to the other two groups.

d. Weak precision in articulation

70% of children with Down syndrome in the study exhibited weak precision in articulation. This error was seen probably due to the hypotonia in the oral structures that was observed in 50% of persons with DS indicating certain degree of dysarthria in these individuals. One-way ANOVA disclosed significant differences across the three groups. The two control groups performed similarly as per Duncan's post-hoc test when compared to the experimental group. Errors other than phonological process errors were tabulated in the task of imitation of words. These errors included groping, disfluencies, distortion errors and weak precision in articulation that were noted down while transcribing the responses of the participants. Persons with Down syndrome exhibited significantly higher numbers of errors than the two control groups. While groping, disfluencies and distortion errors were characteristic of persons having praxis deficits i.e. persons with CAS, weak precision in articulation was perhaps the result of oral motor difficulties, namely hypotonia of oral structures. Apart from these errors, a sequence maintenance score was calculated in order to evaluate how the sequence was maintained the word level task.

4. Sequence maintenance score

Problems in correctly sequencing speech utterances are central to the disorder of apraxia (Hall et al., 1993) and these errors have also been reported in persons with Down syndrome (Rosin et al., 1988; Kumin et al., 1994; Kumin, 1994; Kumin & Adams, 2000). Sequence maintenance score was calculated for each of the forty words that were imitated by the participants. The score was calculated separately for disyllabic and trisyllabic words using a rating from 0 to 2 based on the numbers of syllables repeated in the correct order (refer Appendix 1). The rating scales were used as raw scores and were subjected to statistical analysis using one-way ANOVA. A significant main effect of groups was seen. Table 29 and figure 26 depict results of sequence maintenance score at word level.

Table 29: Means, SDs and F values of sequence maintenance score at word level

Verbal praxis assessment-sentence level	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Sequence maintenance score	41.86	17.69	71.36	5.41	75.26	2.25	80.00	0.00	61.98***

***p<.001

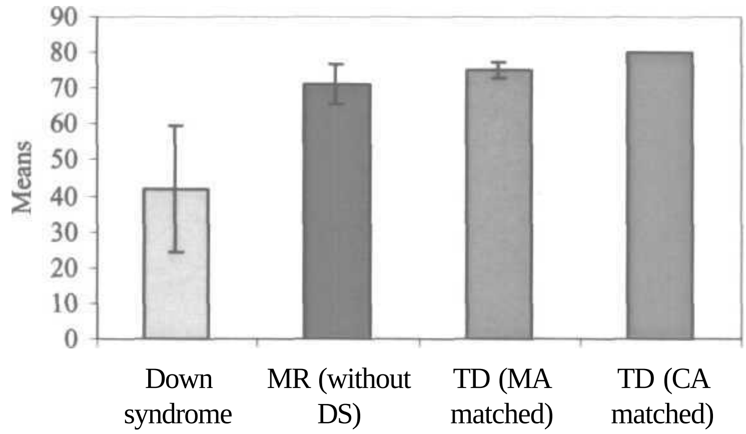

Figure 26: Means and SDs for sequence maintenance score at word level

Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. The scores were subjected to statistical analysis using one-way ANOVA that revealed significant differences across the three groups. While the experimental group was significantly different from the two control groups, Duncan's post-hoc test did not reveal any differences between the two control groups. Higher numbers of errors in sequencing indicate presence of praxis deficits in the individuals with Down syndrome. Raw scores of persons with Down syndrome ranged from 5 to 71 from a total of 80 indicating that some persons performed relatively better than others. Such variability was not observed in the two control groups. Scores of persons with mental retardation (without DS) ranged from 61 to 78 and those of typically developing children ranged from 72 to 78. Results obtained from this part of the word level praxis assessment give an insight into the sequencing errors exhibited by the three groups of participants. Persons with Down syndrome exhibited significantly more difficulties with sequencing than the other two groups indicating praxis deficits. There was also greater heterogeneity within the group with Down syndrome when compared to persons in the control groups. This implies that not all persons with Down syndrome exhibited sequencing errors and hence, praxis deficits.

Word level praxis assessment revealed some important information about verbal praxis deficits in persons with Down syndrome. Phonological processes were tabulated and persons with Down syndrome exhibited significantly more numbers of processes than the two control groups. Some of these phonological errors were suggestive of verbal praxis deficits as reported in persons with CAS. These were observed in significantly higher frequencies than in mental age matched control groups. Other errors suggestive of verbal praxis deficits were also observed such as groping, disfluencies, and distortion errors. Heterogeneity within the group with Down syndrome was apparent from the high standard deviation values that were obtained in the analysis. This goes to show that not all persons with Down syndrome exhibited verbal praxis deficits. Sequence maintenance scores were calculated for each word based on a rating scale and the results obtained also indicated greater problems in persons with Down syndrome than the other two groups. Variability within the group with Down syndrome was also observed in this part of word level praxis assessment. In general, results from word level praxis assessment indicate that persons with Down syndrome had greater praxis deficits than mental age matched control groups but variability within the group existed and that all persons with Down syndrome did not exhibit praxis deficits of the same severity. In order to assess praxis skills in more complex tasks, sentence level praxis assessment was carried out.

E. Sentence level praxis assessment

This section included ten sentences of increasing syllable lengths ranging from three to twelve syllables with every sentence being one syllable longer than the previous one. These sentences were prepared in Kannada for the purpose of assessment of praxis skills at sentence level. A list of thirty sentences with increasing lengths of occurrences was initially prepared and a linguist was consulted to seek advice regarding the dialectal appropriateness of these sentences. These sentences were then subjected to a familiarity rating by 4-5 year old typically developing children on a three point rating scale. Ten 'most familiar' sentences were selected for the protocol. The participants were asked to imitate the ten sentences and the investigator transcribed all sentences. Inter- and intra-transcriber reliability was found to be 78.9% and 82.89% in this section.

The results are presented under three sections:

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

1. Percentage of Consonants Correct

'Percentage of Consonants Correct' (PCC) scores were calculated for each participant's transcribed sample using the formula:

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

Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. Significant differences were observed between the groups. Table 30 and figure 27 depict the results for the PCC metric at sentence level.

Table 30: Means, SDs and F values for PCC scores in sentences.

Verbal praxis assessment-sentence level	Down syndrome (DS)		Mental retardation (without DS)		TD children (MA matched)		TD children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Percentage of consonants correct	44.76	23.00	92.67	8.52	94.17	8.62	100	0.00	82.14***

*** p< .001

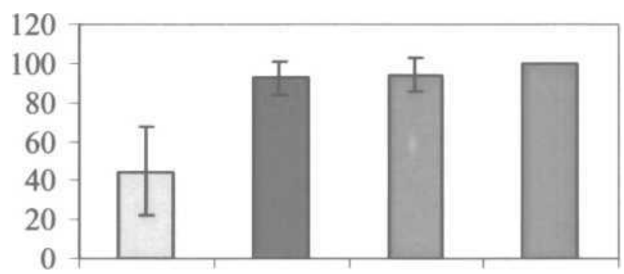

Figure 27: Means and SDs of PCC scores at sentence level

Table 30 reveals significant differences at .001 levels of significance between the groups. Duncan's post-hoc test revealed that while persons with Down syndrome exhibited poorer PCC scores than the control groups, the other groups showed similar scores. The group of persons with Down syndrome however showed more heterogeneity within the group when compared to the control groups as is evident from the standard deviation values in table 30 and figure 27. This indicates that not all persons with Down syndrome had the same severity in terms of percentages of consonants correct. While persons in the group with Down syndrome scored in the range of *2%* to 89.83%, persons with mental retardation (without DS) scored between 67.53 to 100%, as did the mental age matched typically developing children.

All chronological age matched typically developing children scored 100% in this task. It may also be noted that while 66.67% of persons with mental retardation (without DS) and 86.67% from the typically developing groups attained a PCC score of above 90%, none of the persons with Down syndrome could get a score of 90%. Kennedy and Flynn (2003) reported PCC scores in single word imitation tasks ranging between 8 to 82% in 5;5 to 8; 10 year old children with Down syndrome indicating a large individual variability in scores. No studies report PCC scores for sentences in the age range included for this study. In CAS, PCC scores are generally reported for conversational tasks and no studies report PCC scores for sentence level tasks.

2. Percentage of Vowels Correct

'Percentage of Vowels Correct' (PVC) scores were calculated for each participant's transcribed sample using the formula:

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

Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. A significant main effect of group was observed. Means, SDs and F values for the PVC scores in the participants from different groups are depicted in table 31. Figure 28 depicts the means and standard deviations for the four groups of participants. Significant differences were found across the three groups at .001 levels of significance. On Duncan's post-hoc test, persons with Down syndrome showed significantly poorer scores when compared to the control groups.

Table 31: Means, SDs and F values for PVC scores at sentence level

Verbal praxis assessment- sentence level	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	[S.D.	F(2,72)
Percentage of vowels correct	55.90	22.82	97.54	3.75	98.68	1.19	100	0.00	73.69***

***p<.001

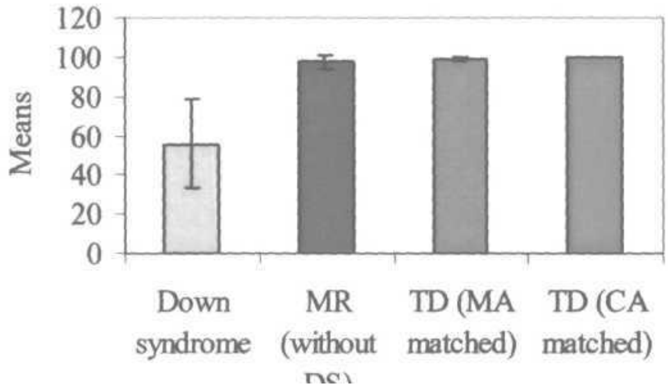

Figure 28: Means and SDs of PVC scores at sentence level

Persons with mental retardation (without DS) and the two groups of typically developing children did not differ from each other in terms of PVC scores. This implies that persons with Down syndrome had greater vowel errors when compared to their mental age matched counterparts. However, there was high variability within the group with Down syndrome as evident from the standard deviation values illustrated in table 31 and figure 28. This was perhaps because not all persons with Down syndrome had difficulties with vowel production in terms of severity. Persons with Down syndrome exhibited a wide range of scores from 4% to 93.2% compared to the group with mental retardation (without DS) and mental age matched typically developing children that scored in the range of 84.84% to 100% and 96.2% to 100% respectively. All the chronological age matched typically developing children obtained 100% scores in this analysis. While 6.66% of the persons with Down syndrome obtained scores above 90%, 93.33% of persons with mental retardation (without DS) and 100% of the typically developing children could score above 90%. PVC scores have not been reported in persons with Down syndrome and in persons with CAS, they are reported only in conversational speech analysis.

PCC and PVC scores in sentence level have not been extensively reported in persons with Down syndrome or CAS. However, persons with Down syndrome exhibited significantly greater deficits when compared to the control groups. More studies in this regard will give a better idea about the relationship between PCC and PVC scores and verbal praxis deficits.

3. Sequence maintenance score

Sequencing problems in speech production are an important indicator of CAS (Hall et al., 1993) and these errors have also been reported in persons with Down syndrome (Rosin et al., 1988; Kumin et al., 1994; Kumin, 1994; Kumin & Adams, 2000). Problems in sequencing indicate the presence of deficits in coordinating and planning the utterances in a word adequately. It is hence a very important indicator of verbal praxis skill deficits. Sequence maintenance score in sentence level was calculated using a three point rating scale from 0 to 2 with 0 representing low scores. This score was based on the numbers of words in the sentence that were imitated in the correct order by the participants. Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. A significant main effect of groups was seen. The raw scores of persons with Down syndrome ranged from 0 to 16. On the other hand, the raw scores of persons with mental retardation (without DS) ranged from 14 to 20 and those of mental age matched typically developing children ranged from 17 to 20. Duncan's post-hoc test revealed that persons with Down syndrome exhibited poorer scores than the control groups. The control groups i.e. persons with mental retardation (without DS), mental age and chronological age matched typically developing children obtained similar scores. Table 32 and figure 29 depict the means, SDs and F values for sequence maintenance score at sentence level for all groups.

Table 32: Mean, SDs, and one-way ANOVA results for sentence level assessment

Verbal praxis assessment-sentence level	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Sequence maintenance score	6.16	4.53	17.83	1.64	19.00	0.92	20.00	0.00	137.93***

*** p< .001

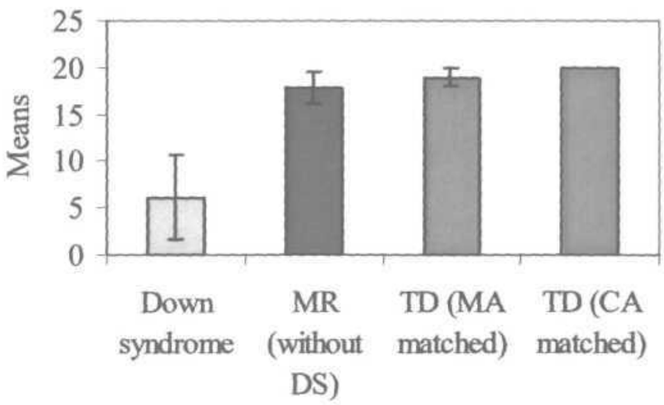

Figure 29: Means and SDs for sequence maintenance score at sentence level.

Increased numbers of errors with increasing complexity is a commonly observed finding in persons with CAS (Hall et al., 1993; Stackhouse, 1992; Robin, 1992; Velleman & Strand, 1994; Forrest & Morrisette, 1999; Lewis et al., 2004). Decreased intelligibility on longer units is suggestive of CAS because it indicates difficulties at the structural level rather than the segmental level. It has also been observed by Kumin and Adams (2000) in persons with Down syndrome. In order to investigate whether sequence maintenance scores decreased as a function of increasing length of sentences, numbers of persons in each group that received a score of lesser than 2 were tabulated for each sentence. The percentage of persons affected per group were then calculated as follows:

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

The percentage of persons in the four groups that received a score of less than 2 are depicted per sentence in table 33 and figure 30. It is clear from table 33 and figure 30 that as sentence length increases, greater frequencies of errors are observed in all the groups of participants. However, numbers of persons exhibiting errors are more in the group with Down syndrome followed by the group of persons with MR (without DS). It may also be noted that while the control groups seldom scored 0, persons with Down syndrome showed an increasing trend of 0 scores as sentence length increased (refer table 33). While 90% of the persons scored 0 in the longest sentence with twelve syllables from the set of stimuli, only 6.66% of them scored 0 in the sentence with the length of three syllables. Kumin and Adams (2000) reported decreased speech intelligibility with increased length of utterance in 5;7 to 13;4 year old children with Down syndrome.

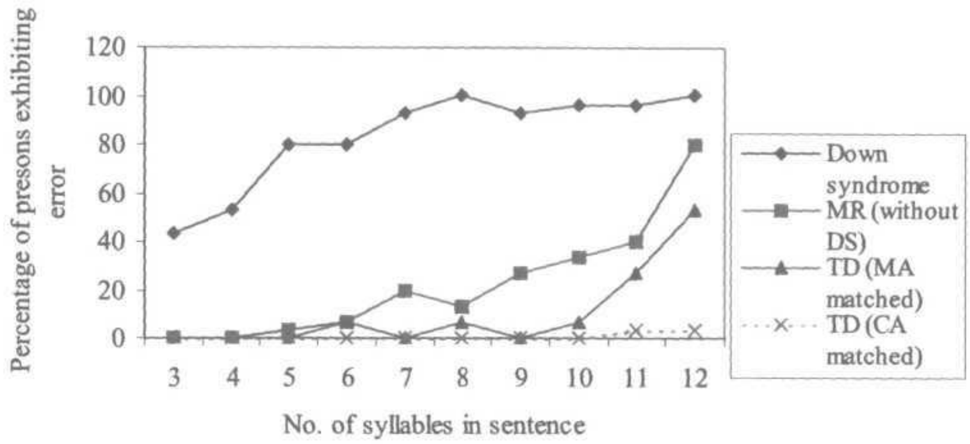

Figure 30: Sequence maintenance score in sentences.

Table 33: Percentage of persons in all four groups of participants exhibiting errors in sentences of differing lengths.

SNo.	Sentence length	Percentage of persons affected			
		Down syndrome	MR (without DS)	Typically developing children (MA matched)	Typically developing children (CA matched)
1.	Three syllables	43.33	0	0	0
2.	Four syllables	53.33	0	0	0
3.	Five syllables	80.00	3.33	0	0
4.	Six syllables	80.00	6.66	6.66	0
5.	Seven syllables	93.33	20.00	0	0
6.	Eight syllables	100.00	13.33	6.66	0
7.	Nine syllables	93.33	26.66	0	0
8.	Ten syllables	96.66	33.33	6.66	3.33
9.	Eleven syllables	96.66	40.00	26.66	3.33
10.	Twelve syllables	100.00	80.00	53.33	0

In sentence level praxis assessment, persons with Down syndrome exhibited considerable praxis deficits as was evident in the results obtained. Statistically significant differences were observed for all three types of analysis. PCC and PVC scores in persons with Down syndrome were significantly greater than those with mental retardation (without DS) and typically developing children. However, the standard deviation value in the group with Down syndrome was suggestive of a diverse degree of speech problems within the same group. PCC and PVC scores supplement the existing data that suggests verbal praxis deficits amongst persons with Down syndrome such as presence of sequencing errors, and increased errors with increasing lengths of utterances. Sequence maintenance scores in sentences give important information about praxis difficulties in terms of increased frequencies of errors with increasing lengths of utterances.

F. Assessment of spontaneous speech

Spontaneous speech samples were collected from each child by asking questions to the child regarding his/her daily activities and indulging in general conversation by using toys and pictures appropriate to their mental age (Venkatesan, 2003). Analysis was carried out for the first hundred utterances collected per child. However for some children, fewer than hundred utterances were recorded. Percentage of consonants and vowels correct (PCC and PVC) were calculated, presence of disfluencies and groping were tabulated per word and phonotactic analysis was also carried out. The results are presented in the following sections:

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

1. Percentage of consonants and vowels correct (PCC and PVC)

All speech samples were transcribed using the broad system of IPA transcription. 10% of the total numbers of spontaneous speech samples were subjected to reliability scoring. Point to point reliability of samples revealed an inter-judge reliability of the transcribed samples as 79.02% and intra-judge reliability as 82.89%. The transcribed samples were analyzed in terms of correct and incorrect consonants and vowels to arrive at PCC and PVC scores. Significant differences were observed across groups for both these analyses as revealed from statistical analyses using one-way ANOVA (Table 34). Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups. A significant main effect of groups was seen for both PCC and PVC scores. Duncan's post-hoc test revealed significant differences between persons with Down syndrome and the other two control groups. The two control groups i.e. persons with mental retardation (without DS) and mental age matched typically developing children however, did not differ significantly for both PCC and PVC scores. Persons with Down syndrome exhibited poorer PCC and PVC scores when compared to the two groups. The means, SDs and F values of the PCC and PVC scores are depicted in table 34.

Table 34: Means, SDs and F values of PCC and PVC scores for spontaneous speech samples

PCC and PVC in spontaneous speech	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		Typically developing children (CA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)= **F**
Percentage of consonants correct	63.33	20.17	96.18	3.96	97.35	2.53	100	0.00	57.98***
Percentage of vowels correct	81.60	12.31	99.25	0.97	99.66	0.51	100	0.00	46.28***

*** p<.001

Persons with Down syndrome exhibited high variability as apparent from the standard deviation values depicted in Table 34. While the group with Down syndrome obtained PCC scores in the range of 21.17% to 92.74%, persons with mental retardation (without DS) scored between 85.65 to 100% similar to the mental age matched typically developing children who scored between 90 to 100%. The chronological age matched typically developing children scored 100%. It may also be noted that while 90% of persons with mental retardation (without DS) and 100% from the typically developing group attained a PCC score of above 90%, only 6.66% of the persons with Down syndrome could get a score above 90%. Large individual variability was noticed in the group with Down syndrome indicating that there are probably subgroups within the group with Down syndrome and those that have poor scores have poorer practic abilities.

Few studies report PCC scores in persons with Down syndrome. Roberts et al. (2005) reported significantly lower PCC scores in 4;3 to 12;9 year old persons with Down syndrome in comparison with Fragile-X syndrome and typically developing children. They reported scores of 71%, 55% and 38% in early-, middle- and late-developing consonants. Low PCC scores are also reported in persons with CAS (Shriberg et al., 1997b, 1997c; Thoonen, Maassen, Gabreels, & Schreuder, 1994; Velleman & Shriberg, 1999; Shriberg & McSweeny, 2002). PCC scores are often used in the Speech Disorders Classification System (Shriberg, 1993) in arriving at a diagnosis of CAS.

PVC scores in persons with Down syndrome were between 50.63% to 95.11% compared to the group with mental retardation (without DS) and mental age matched typically developing children that scored in the range of 96.59% to 100% and 98.26% to 100% respectively. All chronological age matched typically developing children scored 100%. While all persons in the control groups obtained scores above 90%, only 10% of persons with Down syndrome could achieve scores above 90%. PVC analysis in conversational speech in persons with CAS also indicated relatively lower average mastery of vowels (Shriberg et al., 1997b; Shriberg & McSweeny, 2002; Davis, Jacks, & Marquardt, 2005).

PCC scores have been used amongst persons with CAS to indicate severity of errors and also to arrive at a diagnosis of CAS. Vowels are also important to assess in persons with praxis deficits considering their difficulties with vowel production. PCC and PVC scores are important indicators of severity of the problem and also have the potential to serve as indicators of verbal praxis deficits based on severity. They supplement data obtained from other domains indicating verbal praxis deficits.

2. Disfluencies and groping

Disfluencies and groping behaviours were analyzed from the transcribed audio-video samples of spontaneous speech. The occurrences of these behaviours per utterance were noted and the total numbers of occurrences were calculated for each person. One-way ANOVA was carried out on mean raw scores and significant differences were obtained across the three groups of subjects. Since control group II i.e. chronological age matched typically developing children scored 100% in all tasks, one-way ANOVA was carried out only on the other three groups.

A significant main effect of group was seen for both disfluencies and groping. Duncan's post-hoc test revealed significantly higher frequencies of disfluencies and groping behaviours in persons with Down syndrome and no significant differences between the two control groups. A large variability is apparent from standard deviation values in Table 35 in persons with Down syndrome. This suggests that there were differences in persons with Down syndrome in terms of the numbers of disfluencies and groping.

Table 35: Means, SDs and F values for disfluencies and groping during spontaneous speech.

Sentence level	Down syndrome (DS)		Mental retardation (without DS)		Typically developing children (MA matched)		One-way ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
Disfluencies	3.63	7.59	0.33	1.49	0.00	0.00	4.36**
Groping	3.50	6.02	0.00	0.00	0.00	0.00	7.53***

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

It is evident from table 35 that significant differences were present between the groups. Duncan's post-hoc test revealed that persons with Down syndrome exhibited significantly greater disfluencies and groping errors when compared to the control groups. Despite the large variability as depicted by the standard deviation values, the control groups differed significantly from the persons with Down syndrome. The control groups did not differ significantly from one another. Disfluencies were observed in 40% and groping was observed in 33.33% of persons with Down syndrome. On the other hand, disfluencies were observed in 6.66% of persons from the group with mental retardation (without DS) and groping errors were not observed in the two control groups. The kinds of errors noticed were inaudible pauses and phoneme, syllable, part-word and whole-word repetitions.

Persons with Down syndrome are frequently reported to have disfluencies or stuttering in conversational speech of persons with Down syndrome (Otto & Yairi, 1974; Farmer & Brayton, 1979; Van Riper, 1982; Willcox, 1988; Devenney & Silverman, 1990; Preus, 1990; Devenney et al., 1990; Kumin, 1994; Miller & Leddy, 1998). Speech errors such as prolongation, interjections, pauses and repetitions of sounds, syllables, part-words, and whole words have been reported in persons with Down syndrome. Stuttering has also been associated with CAS because both disorders are said to have common central neurological processing deficits (Byrd, & Cooper, 1989). Various reports of stuttering in CAS are present (Aram & Nation, 1982; Hall et al., 1993) and it has even been considered as a CAS error type by others (Rosenbek & Wertz, 1972; Yoss & Darley, 1974). Many clinicians have cited groping or silent posturing of articulators as a commonly observed behaviour amongst children exhibiting apraxia (Crary, 1984b, 1993; Robin, 1992; Hall et al., 1993; Ozanne, 1995; Shriberg et al., 1997a, 1997c; Forrest & Morrisette, 1999; Nijland et al., 2002; Forrest, 2003; Nijland et al., 2003; Lewis et al., 2004). No previous reports of groping in persons with Down syndrome are present.

Disfluencies and groping are suggestive of verbal praxis deficits and have been reported in persons with CAS and Down syndrome. Persons with Down syndrome exhibited significantly higher frequencies of occurrences of disfluencies and groping when compared to the two control groups. It is also imperative to note that not all persons with Down syndrome exhibited these behaviours. There was heterogeneity within the group and all persons with Down syndrome did not exhibit these errors.

3. Phonotactic analysis

'Phontactics' refers to the way syllables behave in utterances and hence reflect on errors that affect an entire syllable or word, especially the structure of the syllable or word. The phonological delays and disorders in children with CAS are described more specifically as belonging to a phonotactic type (Velleman, 1998). Hence, phonotactic analysis was carried out in persons with Down syndrome in order to examine their ability to organize speech sounds in long utterances, such as words and sentences. The following formulae as given by Velleman (1998) were used for calculation of frequency of occurrence of various syllable shapes, word shapes, and clusters in the selected speech samples.

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

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

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

Similar formulae were used to calculate the percentage occurrence of the other syllable shapes (V, VC, CVC), word shapes (mono, tri and multisyllabic words) and different cluster patterns (medial geminated, non-geminated and medial three-sound clusters). All formulae are presented in Appendix 1 and the results are presented in table 36.

Table 36: Means, SDs and one-way ANOVA for different phonotactic patterns

S.No	Phonotactic analysis of spontaneous speech	Down syndrome (DS)		Mental retardation (without DS)		TD children (MA matched)		One-way ANOVA
		Mean	S.D.	Mean	S.D.	Mean	S.D.	F(2,72)
	1. Syllable shapes							
a.	Vowels	8.29	3.99	4.97	1.54	6.15	2.10	10.20***
b.	CV	67.22	6.72	59.56	12.49	60.84	6.97	5.29***
c.	VC	8.76	3.92	12.29	5.13	10.65	2.39	5.19***
d.	CVC	17.66	14.04	25.99	9.60	24.56	2.29	4.80**
	2. Cluster patterns							
a.	Initial clusters	1.00	1.74	3.43	2.10	2.93	1.67	13.31***
b.	Medial geminated clusters	24.75	6.45	26.42	11.84	34.62	7.05	6.14***
c.	Medial non-geminated clusters	13.38	9.52	33.96	9.52	45.36	5.57	75.83***
d.	Medial three-sound clusters	0.14	0.46	2.01	2.48	3.52	1.90	18.94***
e.	Final clusters	0.48	1.05	1.07	1.73	0.91	0.49	1.52**
	3. Word shapes							
a.	Monosyllabic words	10.96	9.11	5.90	5.11	2.19	1.28	9.60***
b.	Disyllabic words	59.44	9.17	47.36	9.07	36.20	6.15	38.52***
c.	Trisyllabic words	22.04	9.63	30.38	7.51	35.77	4.75	16.55***
d.	Multisyllabic words	6.89	5.20	17.42	5.81	25.81	6.63	58.89***

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

Since chronological age matched typically developing children scored 100% on PCC and PVC scores, it was considered more meaningful to compare only the mental age matched groups i.e. persons with Down syndrome, persons with mental retardation (without DS) and mental age matched typically developing children. Phonotactic analysis was carried out for these three groups of participants and the data was subjected to statistical analysis using one-way ANOVA. A significant main effect of groups was seen for most of the syllable shapes, word shapes and cluster patterns. It is evident from the table 36 that significant differences were noted across the three groups for all phonotactic patterns at different levels of significance.

Syllable shapes

The various syllable shapes that were found in the samples analyzed included V, CV, VC and CVC. Figure 31 illustrates the syllable shapes found in children with Down syndrome (DS), mental retardation (without DS) and the typically developing (TD) children. As is evident from figure 31, the patterns in both groups of children with disorders followed the same trend in terms of occurrence of syllable shapes as seen in TD children. As in typically developing children, CV syllables occurred most commonly followed by CVC and VC syllables in the two groups with disorders.

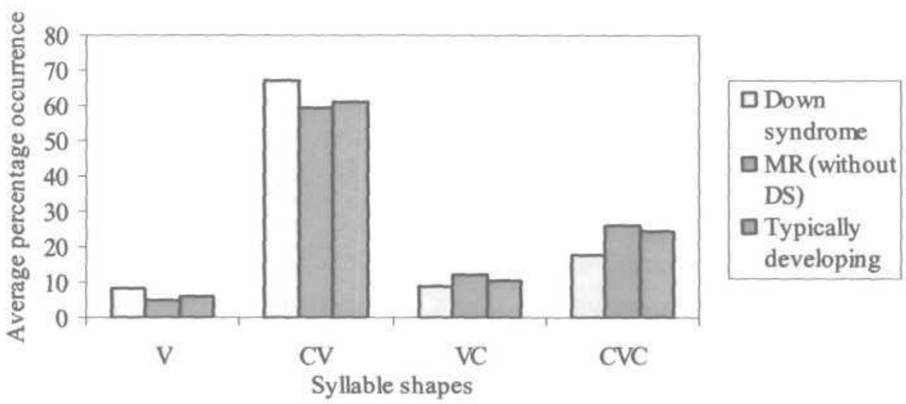

Figure 31: Syllable shapes across children with Down syndrome, mental retardation (without DS) and typically developing children

Duncan's post-hoc test revealed the following results:

- Significant differences were revealed for all syllable shapes between the group with Down syndrome and the two control groups.
- While there were no significant differences between the syllable shapes used by the two control groups, the typically developing children exhibited slightly higher frequency of occurrence of V syllables and CV syllables and slightly lower frequency of occurrence of VC and CVC syllables than the group with MR (without DS).
- An increased frequency of occurrence of V syllables in persons with Down syndrome could be due to presence of increased consonant deletions and decreased use of medial geminated clusters. This led to a decrease in VC syllables and consequently, an increase of V syllables.
- CV syllables are generally acquired earlier and are hence easier to produce than other syllables in Kannada (Rupela & Manjula, 2006). This could be the reason for the predominant occurrence of these syllables in persons with Down syndrome.
- Consequent to the increased use of CV syllables, the frequency of occurrence of VC and CVC syllables was found to be decreased in all three groups of children.

Cluster patterns

The clusters that were found in all participants were initial clusters (CC-, as in /prija/, a name), geminated (-CC-g, as in /əmma/ meaning mother) and non-geminated (-CC-ng, as in /məlgida:re/ meaning '(they are) sleeping' medial clusters and final clusters in borrowed English words (-CC such as, /pænʈ/ meaning 'trousers'). However, medial three sound clusters (-CCC-, as in /əndre/, meaning 'means') occurred only in the two control groups. Final clusters were also observed in borrowed words from English. Figure 32 illustrates the percentage occurrence of different clusters for three groups of children.

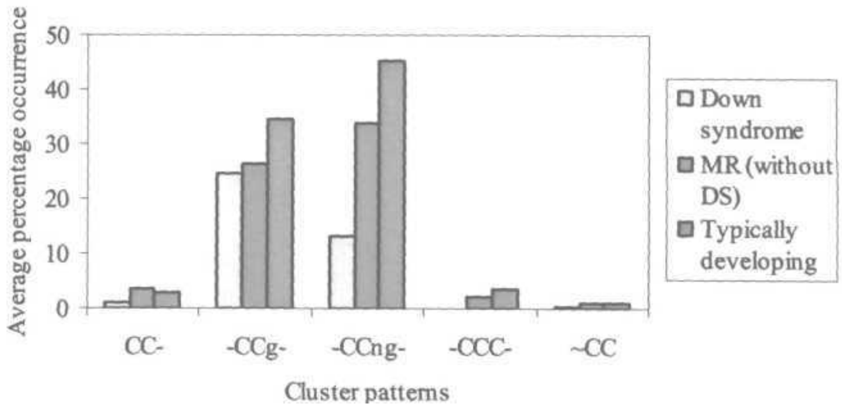

Figure 32: Comparison of cluster patterns across children with DS, mental retardation (without DS) and typically developing children

- Duncan's post-hoc test revealed that typically developing children produced the largest numbers of clusters in their speech indicating that they used the most complex phonotactic patterns with respect to clusters.
- Significant differences across all three groups were observed for medial non-geminated and medial three-sound clusters. Typically developing

children had a higher occurrence of clusters than persons with mental retardation (without DS) followed by the Down syndrome group.

- Persons with Down syndrome exhibited significantly lower occurrence of initial clusters when compared to the two other groups probably because they are acquired later than the medial clusters in Kannada (Rupela & Manjula, 2006) and hence are more difficult phonotactically.
- They also produced significantly lower numbers of medial non-geminated clusters and medial three-sound clusters when compared to the other two groups indicating that they might have had difficulty in using two or three different consonants together in the medial position as required for forming medial clusters.
- A slightly different pattern was observed in the use of geminated clusters where no significant differences were found between the two groups with disorders for geminated clusters. Medial geminated clusters are the first to be acquired by typically developing children (Rupela & Manjula, 2006) and are easier to produce than other clusters. The group with Down syndrome used mostly medial-geminated clusters and performed as well as the group with mental retardation (without DS).
- No significant differences were observed between the two control groups in terms of final clusters as their occurrence was limited to the use of borrowed English words by the participants.

Word shapes

Monosyllabic, disyllabic, trisyllabic and multisyllabic words were found in the samples of all three groups of participants. Figure 33 indicates that typically developing children used higher numbers of tri- and multisyllabic utterances than di- and monosyllabic utterances.

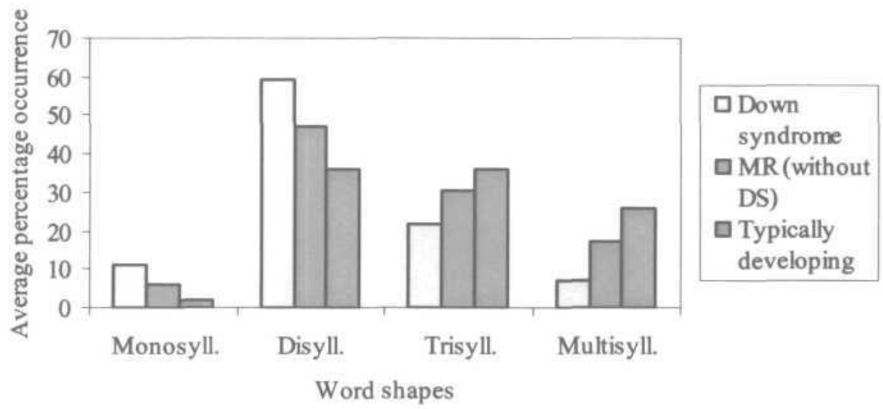

Figure 33: Comparison of word shapes across children with DS, mental retardation (without DS) and typically developing children

- Duncan's post-hoc test reveals that except for the frequency of use of monosyllabic words where no significant differences were noticed between the two control groups, all three groups differed significantly with one another for the other word shapes. Monosyllabic words do not occur commonly in Kannada in adults (Nayak, 1967) as well as children (Rupela & Manjula, 2006). In persons with Down syndrome, syllable deletions also contributed to the formation of monosyllabic words and this was probably the reason for the significant differences.

- Both groups of children with disorders used significantly higher percentages of disyllabic words than typically developing children, probably because disyllabic words are the easiest and ones to be produced earlier by typically developing children (Rupela & Manjula, 2006)
- The increased use of disyllabic words in both groups resulted in the decreased use of trisyllabic and multisyllabic words when compared to typically developing children. This difference was significant for all three word shapes.
- Amongst the two groups with disorders, children with DS used significantly lower numbers of trisyllabic and multisyllabic words.
- Although the children with mental retardation (without DS) used a lower percentage of multisyllabic words than the typically developing children, the maximum numbers of syllables in words used by them was six, which was similar to the maximum number found in 4 - 5 year old typically developing children. On the other hand, children with DS used a maximum of four syllables in multisyllabic words.

Phonotactic analysis provides an insight as to how children are able to use different speech sounds in the context of its adjacent sounds. Previous research suggests several types of phonotactic deficits such as, increased omissions, increased errors with increased length of utterance, and difficulty in using multisyllabic words as being associated with CAS. Several researchers have hypothesized that the underlying deficit in CAS is in the syllabic framework (Davis et al., 1998; Marquardt et al., 2002; Maassen, 2002; Nijland, et al., 2003). Other researchers have postulated sequencing as the primary deficit (Thoonen et al., 1996). Davis et al. (1998) proposed 8 key characteristics of CAS, including frequent omissions, increased errors on longer units, and predominant use of simple syllable shapes. Lewis et al. (2004) found that children with CAS who were followed from preschool into school age differed from children with speech disorders at school age in having more syllable sequencing errors in conversational speech than the speech-delayed children. Thoonen et al. (1996) also noted that multisyllabic word tasks were critical for differentiating CAS from dysarthria. Thus, phonotactic difficulties have often been noted as being important to the diagnosis of CAS. Analyses in this study revealed that some of these characteristics exist in children with Down syndrome when compared to children with developmental delay and those developing typically.

In assessment of spontaneous speech, persons with Down syndrome exhibited considerable praxis deficits as was evident in the results obtained. Statistically significant differences were observed for all three types of analysis. PCC and PVC scores in persons with Down syndrome were significantly greater than those with mental retardation (without DS) and typically developing children. However, the standard deviation values in the group with Down syndrome were suggestive of a diverse degree of speech problems within the same group. Disfluencies and groping errors in spontaneous speech also suggested considerable deficits in verbal praxis skills. Phontactic difficulties were revealed on analysis of the different syllable, word and cluster shapes. Phonotactic analyses revealed that syllable shapes characteristic of CAS exist in children with Down syndrome in terms of decreased use of difficult patterns such as initial clusters, medial three-sound clusters, CVC syllables and multisyllabic words. Persons with Down syndrome also tended to use simpler phonotactic patterns like medial geminated clusters, CV syllables and fewer clusters.

Summary of results

An assessment protocol was used to assess oral motor, oral praxis and verbal praxis skills in persons with Down syndrome in comparison with mental age matched persons with mental retardation (without DS) and mental and chronological age matched typically developing children. While chronological age matched typically developing children obtained full scores in almost all tasks, various degrees and types of difficulties were observed across the other three groups of participants. In general, persons with Down syndrome showed poor performance across most of the tasks when compared to the control groups. Variability within the group with Down syndrome was apparent and suggested that not all skills were affected in all persons in this group. Persons with mental retardation (without DS) also obtained poor scores when compared to typically developing children for some tasks, but got similar scores for the most part. The assessment provided an insight into the presence of oral motor and praxis skill deficits in persons with Down syndrome and explored the possible presence of Childhood Apraxia of Speech.

- Oral motor assessment in the group with Down syndrome revealed poor scores in position of jaw, and placement tongue in the mouth indicating the presence of hypotonia of the jaw and tongue.
- Function of the oral mechanism for speech including intraoral breath pressure and precision for stops, fricatives and velopharyngeal mechanism were more affected in persons with Down syndrome when compared to the control groups.
- Persons with Down syndrome exhibit significantly greater deficits in oral praxis skills in terms of both isolated movements, and sequential oral movements. In isolated oral movement tasks, persons with Down syndrome exhibited greater errors both in terms of accuracy and sequence when compared to the control groups.
- Sequential oral movements assessment revealed distinct difficulties of persons with Down syndrome to imitate a sequence of two oral movements together. Sequencing oral movements was a more difficult task than isolated oral movements for assessment of oral praxis skills and this assessment clearly indicated praxis breakdown in terms of planning out two movements sequentially.
- Verbal praxis assessment was carried out hierarchically including isolated, sequential verbal movements, DDK tasks, word level, sentence level assessment and assessment of spontaneous speech.
- Scores obtained from isolated verbal movement assessment revealed that speech sounds that involved predominantly tongue movements were most difficult for all groups of participants. However, persons with Down syndrome exhibited greater numbers of errors when compared to the control groups.

- Persons with Down syndrome exhibited poorer accuracy and sequencing of two and three-sound movements in the sequential verbal movement assessment. Persons with mental retardation (without DS) also exhibited some amount of sequencing problems when compared to typically developing children indicating that they perhaps had verbal praxis deficits as well, but not as severe as in persons with Down syndrome.
- Assessment of diadochokinetic tasks revealed that persons with Down syndrome had more difficulties than the control groups in maintaining the sequence of syllables in the SMR tasks. Significant differences in terms of rate were present between persons with Down syndrome and control groups for SMR but not for AMR tasks. Difficulties in the SMR tasks reveal distinct deficits in verbal praxis skills.
- For DDK tasks, persons with Down syndrome also differed from the control groups in terms of numbers of attempts taken, accuracy in terms of articulation for AMR and SMR tasks, and consistency of repetitions in SMR tasks. Persons with Down syndrome required greater numbers of attempts, exhibited more errors of articulation such as, place, voicing, deletion, and perseveration errors. They also showed greater inconsistencies from one repetition to another (in SMR tasks) than the control groups.
- At word level, phonological process analysis revealed that persons with Down syndrome exhibited greater numbers of different phonological processes both in terms of percentage occurrences and frequencies of persons affected in the different groups. Specific errors in the verbal praxis domain were also noted such

as, sequencing errors, high degree of omissions, vowel errors, voicing errors, groping, and disfluencies. Sequence maintenance score was also calculated in all participants and persons with Down syndrome exhibited poorer scores than the control groups.

- Sentence level assessment reveal praxis deficits in terms of poorer PCC and PVC scores, and increased errors with increasing sentence lengths in persons with Down syndrome than the control groups.
- Assessment of spontaneous speech also revealed poorer PCC and PVC scores in addition to greater groping and disfluencies in persons with Down syndrome.
- Phontactic analysis in spontaneous speech revealed praxis breakdown in terms of the inability to use two or three consonants together in cluster patterns such as initial clusters, and medial three-sound clusters. Furthermore, the later acquired patters such as CVC syllables and multisyllabic words were lesser in frequency of occurrence in persons with Down syndrome when compared to the control groups. Persons with Down syndrome also tended to use simpler phonotactic patterns like medial geminated clusters, CV syllables and fewer clusters.

Amongst all tasks in the protocol, there were certain tasks that were more suggestive than others in terms of identification of oral and verbal praxis deficits in persons with Down syndrome. These are depicted in Appendix 3 and the details are listed as follows:

- Comparison between other isolated oral movements and tongue movements. When percentage scores are calculated, other movements are significantly more affected than tongue movements.
- Sequential motor score from sequential oral movement assessment.
- Sequential motor score from sequential verbal movement assessment.
- DDK rate assessment of SMR task.
- Consistency in SMR task of DDK assessment.
- Sequential motor score from word level praxis assessment.
- Presence of greater timing and whole word errors than space errors in percentage occurrence of phonological processes.
- Sequence maintenance score of sentence level praxis assessment.
- Greater frequency of CV, V syllables, disyllabic words, geminated clusters; and lesser CVC syllables, multisyllabic words, initial clusters, three-sound medial clusters on phonotactic analysis.

Oral motor, oral praxis, and verbal praxis skills were evaluated in persons with Down syndrome in comparison with three control groups: persons with mental retardation (without DS), mental age matched typically developing children and chronological age matched typically developing children. For all three skills, persons with Down syndrome showed more deficits when compared to the control groups.

SUMMARY AND CONCLUSIONS

Down syndrome is a chromosomal abnormality that gives rise to a varied and extensive range of language and speech disorders. Individuals with Down syndrome are reported to have skeletal and muscular systems that differ from those individuals without Down syndrome (Miller & Leddy, 1998; Leddy, 1999). Hypotonia, weakness in oral structures, limited movements of oral structures; deficits in the structure of the oral cavity (a high palatal vault) and tongue size in relation to oral cavity are reported to affect speech production in persons with Down syndrome. Some investigators have also evaluated the presence of motor planning and co-ordination or praxis deficits i.e. Childhood Apraxia of Speech in persons with Down syndrome. Few investigations to assess oral and verbal praxis deficits i.e. CAS as a secondary disorder in persons with Down syndrome have been carried out (Ferry et al., 1975; Elliott et al., 1990; Hamilton, 1993; Kumin & Adams, 2000).

This study was conducted analyze the oral motor, oral praxis and verbal praxis skills in Kannada speaking persons with Down syndrome in the age range of 11;6 to 14;6 years. The experimental group i.e. persons with Down syndrome were compared with mental and chronological age matched persons with mental retardation (control group I), and two groups of typically developing children. The typically developing children included mental age matched children between 4;1 and 6; 10 years of age (control group III) and chronological age matched children (control group II). Thirty children each were included from the groups with Down syndrome (DS), mental retardation (without DS) and typically developing children (15 each from control groups II and III).

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

All children were tested individually; in fairly quiet and familiar surroundings and samples were recorded using a Panasonic digital camcorder NV GS-15 supplemented with audio recordings using a digital voice recorder. Video recording was started whilst administration of the test battery where positive feedback and appropriate cues were given in order to elicit the speech. The recorded audio-video samples were viewed on a 17 inches wide computer monitor and analyzed by using headphones. All samples were analyzed individually and scores were compiled in a scoring sheet. Transcription was carried out using broad IPA transcription method along with a few diacritic markers. Reliability measures were done by three judges (including the investigator) in order to establish the reliability of the protocol, scores as per rating scales and that of IPA transcription. Statistical analyses were carried out to compare the participant groups for their performance across the three skills assessed.

Responses of all participants in the groups for tasks used to assess oral motor, oral praxis and verbal praxis skills were analyzed. The salient findings of the study are as follows:

/. Oral motor skills

A. Oral structures at rest

- Persons with Down syndrome exhibited greater problems in oral motor skills than the other three groups.

- Persons with Down syndrome significantly differed from persons with mental retardation (without DS) who in turn differed from the mental age matched typically developing group.
- Persons with Down syndrome exhibited poorest performance for 'other' movements (puffing up of cheeks and clearing of throat) followed by tongue movements.
- In control groups, tongue movements were most affected and 'other' movements were least affected.
- There was more heterogeneity within the group with Down syndrome than in the control groups indicating that not all persons in this group exhibited oral praxis deficits for isolated oral movements.

B. Sequential oral movements

- Persons with Down syndrome exhibited significantly greater oral praxis problems in sequential movements than the control groups both in terms of accuracy (motor control score-MCS) and sequence (sequential motor score-SMS).
- Persons with mental retardation (without DS) on the other hand, exhibited lesser numbers of errors than persons with DS in terms of accuracy, but significantly greater numbers of errors when compared to mental age matched typically developing children. In terms of sequencing, they did not exhibit any differences when compared to the mental age matched typically developing group.

///. Verbal praxis skills

A. Isolated verbal movements

- Significantly greater deficits when compared to the control groups I and III were noticed in persons with Down syndrome both in terms of accuracy and numbers of cues required for performing isolated verbal movements.
- Speech sounds that involved predominantly tongue movements were more affected in all the three groups.
- There were a few differences across the three groups. While persons with Down syndrome had more problems in producing the continuant 's', the other two groups had more difficulty in producing the continuant '1'.
- Impairments in isolated oral movements in persons with Down syndrome could be due to hypotonia. Hence, in order to specifically address praxis deficits, verbal movements in sequence were also assessed.

B. Sequential verbal movements

- Persons with Down syndrome exhibited poorer accuracy and sequencing of two and three-sound movements when compared to the control groups.
- While control groups I and III did not differ from each other in the 'motor control score', persons with mental retardation (without DS) exhibited significantly

poorer scores than typically developing children in the 'sequential motor score' and not the 'motor control score'.

C. Assessment of diadochokinetic tasks

- Significant differences were present between the group with Down syndrome and the control groups in terms of rate for the SMR (sequential motion rate) task and not for the AMR (alternate motion rate) tasks.
- Persons with Down syndrome also required significantly greater numbers of attempts and more numbers of articulation errors of place, voicing, deletion, exchange and perseveration when compared to the control groups.
- A high inconsistency was evidenced in persons with Down syndrome in repeating and maintaining sequence of syllables in SMR tasks indicated poorer praxis control.

D. Word level praxis assessment

- Persons with Down syndrome exhibited an increased use of many phonological processes both in terms of percentage occurrence and frequency of persons affected.
- Whole word errors were mostly observed in persons with Down syndrome followed by space and timing errors. On the other hand, the two control groups

exhibited mostly space errors followed by whole word and timing errors indicating praxis breakdown.

- Phonological errors suggestive of praxis deficits such as presence of high degree of omissions (consonant and syllable deletions), sequencing errors (cluster reduction, metathesis, migration etc.), atypical errors (errors unexplained by phonological error categories), voicing (prevocalic voicing and postvocalic devoicing) and vowel errors (centralization, prolongation, lowering, raising, decentralization) were also present in persons with Down syndrome.
- Sequence maintenance in terms of the numbers and sequence of syllables in words was also more affected in persons with Down syndrome when compared to the control groups.

E. Sentence level praxis assessment

- Persons with Down syndrome obtained significantly poorer percentage of consonants correct (PCC) score and percentage of vowels correct (PVC) scores compared to the control groups. Both PCC and PVC scores showed a higher variability in persons with Down syndrome when compared to the control groups.
- Sequence maintenance score in sentence level was also calculated for all participants. As sentence length increased, greater frequencies of errors were more evident in the group with Down syndrome followed by the MR (without DS) group indicating distinct deficits in verbal praxis skills in persons with Down syndrome.

F. Spontaneous speech assessment

- Persons with Down syndrome exhibited poorer PCC and PVC scores when compared to the two control groups I and III. A higher range of PCC and PVC scores were noted in persons with Down syndrome when compared to the control groups.
- Significantly higher frequencies of disfluencies and groping behaviours were observed in persons with Down syndrome and no significant differences were seen between the two control groups.
- Significant differences were revealed between persons with Down syndrome and the control groups I and III i.e. persons with mental retardation without DS and mental age matched typically developing children for phonotactic assessment. An increased use of V syllables, CV syllables, disyllabic words, and geminated clusters; and a decreased use of CVC syllables, multisyllabic words (5-6 syllables), initial, medial three-sound and medial non-gemianted clusters indicated praxis breakdown in persons with Down syndrome.

Persons with Down syndrome were assessed for oral motor, oral praxis and verbal praxis skills by using an assessment protocol for the evaluation of these skills. In all three domains, viz. oral motor, oral praxis and verbal praxis skills, persons with Down syndrome exhibited more deficits than the control groups that included persons with mental retardation (without DS) and typically developing children. Oral and verbal praxis deficits were present along with oral motor deficits such as hypotonia in persons with

Down syndrome. However, most of the oral and verbal praxis deficits could be differentiated from oral motor skill deficits by the use of tasks that evaluated praxis breakdown relatively independent of oral motor deficits. For example, sequencing errors in both oral and verbal domains were due to praxis deficits and were not attributable to sluggish movements of oral structures due to hypotonia. Persons with mental retardation (without DS) performed poorly in oral praxis skills when compared to the mental age matched typically developing children, but at par with them in verbal praxis skills. Overall, while oral praxis deficits were noted in varying degrees in both groups of disorders, viz. persons with Down syndrome and persons with mental retardation (without DS), verbal praxis deficits were distinctly noted in persons with Down syndrome. Certain tasks from the protocol were better indicators of oral and verbal praxis breakdown in persons with Down syndrome when compared to the persons with mental retardation (without DS). Those included assessment of sequencing in oral and verbal praxis assessment domains, assessment of consistency in SMR tasks of DDK, and phonotactic analysis. All these tasks have been presented in Appendix 3.

Future directions

Research in its true form always brings more questions than answers. The present study is a preliminary attempt in understanding praxis deficits in persons with Down syndrome. More research is needed in future to comprehensively evaluate praxis deficits in persons with Down syndrome. Future directions to fulfill this may include:

- Objective measurements using acoustic, and kinematic measures to evaluate oral and verbal praxis breakdown in persons with Down syndrome.
- Therapeutic intervention principles in line with treatment protocols typically adopted for persons with Childhood Apraxia of Speech could be used in order to behaviorally evaluate whether a positive effect is brought about by these intervention strategies.
- Identification of a genetic marker for CAS in the 21st chromosome, making use of evidence that persons with Down syndrome have praxis deficits could be carried out. Markers in the 21st chromosome could reveal information of considerable importance.

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APPENDIX 1

ASSESSMENT TOOL FOR ORAL MOTOR, ORAL PRAXIS AND VERBAL PRAXIS SKILLS

Name:

Date:

Age/Gender:

Education:

School:

IQ level as per psychologist's report:

Medical history: H/o otitis media-if yes, how many episodes:
Epilepsy:
Major illness:

Other relevant information:

I. ORAL MOTOR ASSESSMENT

A. POSTURE

1. Score 1 if the answer is 'yes' and 0 if the answer is 'no'

a) Does the child sit up straight? Yes/No
b) Are his/her shoulders symmetrically positioned? Yes/No
c) Is the child's head/neck in a normal alignment with shoulders? Yes/No

2. Score 1 if the answer is 'no' and 0 if the answer is 'yes'

a) Are there any involuntary movements present in the child's head, shoulders and/or trunk? Yes/No
b) Does the child's mouth position improve when placed in 90° hip, knee and ankle flexion? Yes/No

3. Instruct the child to imitate the following movements. Circle the choice found appropriate for each. Score 1 for 'adequate' and 0 for 'inadequate'.

a) Forward and backward movement of head Inadequate/Adequate
b) Rotation of the head Inadequate/Adequate
c) Left-right movement of the head Inadequate/Adequate
d) Left-right movement of the shoulders Inadequate/Adequate
e) Left-right movement of the trunk Inadequate/Adequate
f) Forward and backward (bending front and back) movement of the trunk Inadequate/Adequate

B. ORAL STRUCTURES AT REST

Score 2 for 'a', 1 for 'b' and 0 for 'c'.

1. The child's jaw is:
a) In normal alignment
b) Slightly protracted or retracted
c) Noticeably protracted or retracted

2. The child's jaw at rest is:
a) Closed
b) Slightly open
c) Noticeably open

3. The child's lips are:
a) In a normal position
b) Slightly protruded or retracted
c) Obviously protruded or retracted

4. The child
a) Does not drool
b) Drools, but tries to swallow it
c) Drools and does not use any strategy to clear it

5. The child's tongue is:
a) Placed appropriately inside the mouth
b) On the bottom of the lower lip
c) Outside the mouth

6. Based on the interpretation from the five items above, the oral structures seems to show
a) Normal tone
b) Mildly abnormal tone
c) Moderately abnormal tone

7. Involuntary movements are:
a) Absent
b) Present but barely noticeable
c) Apparently present

8. When the child moves his/her oral structures:
a) Other parts of the body do not move
b) Other parts of the body move minimally
c) Other parts of the body move noticeably and hinder in speech production

C. FUNCTION OF THE ORAL MECHANISM FOR SPEECH

Score 1 for 'adequate' and 0 for 'inadequate'

1. The intra-oral air build-up for stops is	Adequate/Inadequate
2. Air build up and precision of fricatives is	Adequate/Inadequate
3. Oral-nasal distinction is	Adequate/Inadequate

The following activities have to be observed without asking the child to imitate or do these activities:

4. When the child spreads his lips, the range of movement of lips is	Adequate/Inadequate
5. When the child opens and closes his/her mouth, range of movement of jaw is	Adequate/Inadequate
6. When the child moves the tongue from side to side, the range of movement is	Adequate/Inadequate

D. ORAL SENSORY BEHAVIOUR

The following questions regarding the child are explained to the parent(s) or caregiver and asked how frequently the behaviours are exhibited based on the key given below.

(N) Never
(0) Occasionally
(F) Frequently
(A) Always
(NA) Not applicable

	Questionnaire	N	O	F	A	**NA**
1	Reacts aversively to new foods, tastes or textures- limited food repertoire					
2	Avoids certain texture of foods					
3	Has poor lip closure (due to discomfort of closing lips together)					
4	Is uncomfortable when touched on face/cheeks/lips					
5	Likes only highly textured or crunchy foods.					
6	Has trouble handling liquids					
7	Chews or swallows ineffectively due to lack of awareness of food in the mouth					
8	Constantly puts things in the mouth					
9	Bites himself or others					
10	May not notice if food offered is too hot or cold					
11	Demonstrates poor oral motor skill development (biting, chewing, swallowing)					
12	Is unaware of food stuck in the teeth or on side of lips/face					
13	Is unaware of pooled saliva and drooling					
14	Chews hard on things.					
15	Explores foods by tasting					
16	Chews constantly on non-food items- wants to taste everything					
17	Acts as though all foods taste same-disinterested or bored with eating-poor appetite-fussy while eating					
18	Only seems to taste foods that are highly spiced					
19	Messy eater-frequently spills					

The scoring is done as follows:

0- Never (N)
1- Occasionally (O)
2- Frequently (F)
3- Always (A)
0- Not applicable (NA)

II. ORAL PRAXIS ASSESSMENT

A. ISOLATED ORAL MOVEMENTS

The child is asked to imitate the following movements.

Action	Accuracy	Rate	Repetitions	Score
Jaw movement				
1. Click teeth together once				
2. Open your mouth				
3. Close your mouth				
4. Hold your mouth open at midrange				
Lip movement				
5. Smile				
6. Pucker lips				
7. Bite lower lip				
8. Blow				
9. Pretend to kiss				
Tongue movement				
10. Stick out your tongue				
11. Lick your lips with tongue				
12. Touch the nose with tip of tongue				
13. Move your tongue in and out				
14. Move your tongue to the right				
15. Move your tongue to the left				
16. Click your tongue				
17. Wiggle your tongue from side to side				
Others				
18. Clear your throat				
19. Puff up your cheeks				

The accuracy and rate are evaluated based on the number of repetitions provided. All responses are scored based on rate, accuracy and cues used as follows:

4- Movement/action is accurate and rate is appropriate
3- Movement/action is accurate and rate is appropriate with one repetition
2- Either movement/action or rate is inappropriate with more than one repetition
1- Both are inappropriate with more than one repetition
0- Child is unable to perform even with repetitions

Action	Accuracy	Repetitions	Score
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 /ʈə/,			
19. Say /ɖə/			
20. Say /ʧə/			
21. Say /rə/			
22. Say 'shh…'			

The speech movements are scored based on rate, accuracy and cues used as follows:

3- Movement/action is accurate
2- Movement/action is accurate with one repetition
1- Movement/action is inappropriate with more than one repetition
0-Child is unable to perform even with repetitions

B. SEQUENTIAL VERBAL MOVEMENTS

The child is asked to imitate the following sequential verbal utterances:

SNo.	Stimulus	Transcribed response	MCS	SMS
1	a-u			
2	o-i			
3	m-u			
4	a-m-u			
5	u-i-a			
6	i-u-a			
7	m-o-i			

Two types of scores are given as follows:

Motor control score (MCS):
2- All movements are precise
1- One of the movements is imprecise
0- All movements are imprecise or child substitutes one phoneme for another or child does not say all phonemes

Sequence maintenance score (SMS):
2- Repeats all phonemes correctly
1- Repeats 2 out of 3 oromotor sequences correctly or repeats the oromotor phonemes 5 or 6 times
0- Repeats one out of 3 oromotor sequences correctly or repeats the oromotor phoneme sequence more than 6 times

If the child does not respond, write NR next to the column

C. ASSESSMENT OF DIADOCHOKINETIC (DDK) TASKS

The child is asked to repeat the stimuli 'pə', ʈə', 'kə' and 'pəʈəkə' as fast as possible. Time taken for completing at least 10 repetitions is calculated. Indicate the number of attempts needed to complete 10 iterations and whether sequence is maintained in the repetition of 'pataka'.

No.	Stimulus	Time taken for 10 iterations	DDK (it/sec)	Sequence for 4 repetitions	Number of attempts
1.	pə				
2.	ʈə			-	
3	kə				
4	pə-ʈə-kə				

Consistency of DDK task (pə-ʈə-kə):

Keeping the first pə-ʈə-kə utterance as reference, evaluate the consistency of the task as follows:

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

D. WORD LEVEL PRAXIS ASSESSMENT

The **child** is asked to repeat the following words after the investigator.

Target	Transcribed response	Phonological Errors			Groping	Dysflu encies	Weak precision	SMS
		SE	TE	WWE				
tale								
si:re								
məne								
se:bu								
na:ji								
bekku								
pennu								
tʃ^{h}ətri								
təʈʈe								
su:rja								
ba:gilu								
huɖugi								
kiʈəki								
tʃəmətʃa								
kudəlu								
ba:gilu								
da:ɭimbe								
pustəka								
tʃəppəli								
i:ruɭɭi								
ərəməne								
əɖigeməne								
ba:tʃəɳige								
gəɖija:ra								
ga:ɭipəʈa								
kənnəɖəka								
ba:ɭehəɳɳu								
de:vəst^{h}a:na								
a:lu:gəɖɖe								
teŋginəka:ji								
kriʃɳa								
driʃja								

Target	Transcribed response	Phonological Errors			Groping	Dysfluencies	Weak precision	SMS
		SE	TE	WWE				
prəʃne								
swətʃtʃʰa								
vaidja								
vjəvəstʰe								
pra:tʰəmika								
brəmhərʃi								
svərgəstʰa								
prəkʃubdʰa								
Total scores								

The errors are transcribed and total number of errors is counted. A score of' 1' is given for each error.

Key for scoring errors:

Space errors *(SE):* fronting, backing, palatalisation, depalatalisation; and vowel deviations including vowel prolongation, vowel shortening, vowel centralization, vowel decentralization, monophthongization, diphthongization, vowel raising and vowel lowering.

Tinting errors (TE): voicing errors, affrication, deaffrication, denasalization, gemination and degemination of consonants.

Whole word errors (WWE): cluster reduction, reduplication, consonant harmony, migration, metathesis, epenthesis, initial consonant deletion, medial consonant deletion, initial, medial and final syllable deletions

Groping errors: Self-corrections or change of position of articulators- silent groping. False starts-audible groping

Dysfluencies: repetitive production of speech sounds, hesitations, pauses

Weak precision: when there is weak approximation of active articulator with passive articulator.

Sequence maintenance score (SMS): *Disyllabic words*

2- Repeats both syllables in the correct order

1- Repeats both syllables in reverse order or repeats a syllable or adds/deletes a syllable

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

If the child does not respond, mark NR and score 0

Sequence maintenance score: *Trisyllabic and multisyllabic words*

2- Repeats all syllables in the correct sequence

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

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

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

Note: Do not penalize the child for consonant/vowel substitution unless where consonant/vowel harmony and cluster reduction occurs as repetition of syllables takes place

E. SENTENCE LEVEL ASSESSMENT

The child is asked to repeat the following sentences after the investigator.

Target	Transcribed response	SMS
illi ba		
ədu məra		
na:n bərijəlla		
nənge ʤvəra idɛ		
a karu hogta idɛ		
sku:ləlli ʧənna:g o:dbeku		
məisu:rəlli ərməne idɛ		
gaɭipəʈa məgu kəijəllidɛ		
nəmənɳa ka:fi kuɖita iddare		
nenne əmma nənge məisur pa:k ma:ɖkoʈru		

The following calculations are done:

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

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

Sequence maintenance score

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

1- Sentences with < 3 words- At least 1 word is in order
   Sentences with > 3 words-At least 3 of the key words are in order

0- Sentences with < 3 words- 0 words in order
   Sentences with > 3 words- 2, 1 or no key words are in order

F. ANALYSIS OF SPONTANEOUS SPEECH SAMPLE

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

Transcribed sample:

The following calculations were done:

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

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

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

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

Phonotactic analysis: Calculate the different types of syllables (V, CV, VC, CVC), words (mono-, di-, tri-, multi-syllabic) and clusters (initial, medial geminate, medial non-geminate, medial three-sound, final) from the words to calculate their percentage occurrences.

Percentage occurrences of different types of syllables

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

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

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

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

Percentage occurrences of different types of words

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

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

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

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

Percentage occurrences of different types of clusters

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

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

$$\frac{\text{Number of medial non-geminate clusters}}{\text{Total number of words}} \times 100 = \%\ \text{medial non-geminate clusters}$$

$$\frac{\text{Number of medial three-sound clusters}}{\text{Total number of words}} \times 100 = \%\ \text{medial three-sound clusters}$$

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

APPENDIX 2

IDENTIFICATION CHECKLIST

With permission from Project on 'Prevention of Communication Disorders',
Department of Speech Pathology,
All India Institute of Speech and Hearing, Mysore-6

General

1. Is there any positive family history of genetic/hereditary disorder?
2. Is there any history of anoxia, infection, trauma, and accidents during or after the birth of the baby?

Voice

1. Does the child have too soft/loud voice?
2. Does the voice of the child sound hoarse/harsh/breathy?
3. Does the child complain of persistent hoarseness of voice, difficulty in swallowing or breathing?
4. Does the child have a deviant pitch compared to similar age and sex group?

Articulation Disorder

1. Is the child unable to produce one or more sounds of his/her language even at the age of 6 years?
2. Does the child articulate speech sounds in such a way that it is not clearly understood by others?
3. Has the child undergone any surgery for cleft of the lip or palate?

Dysfluency

1. Does the child speak too fast and his/her speech is unintelligible/not understood by listeners?
2. Does the child speak with dysfluency such as repeating, prolonging, pausing, or breaking the word while speaking?

Reading/Learning disability (Dyslexia)

1. Does the child exhibit difficulty in left-right orientation?
2. Does the child have difficulty/inappropriate way of holding a pen?
3. Does the child show difficulty with tasks requiring sequencing?
4. Does the child have reversal in reading and writing?
5. Does the child lose place frequently when reading?
6. Does the child have continued failure even after constant guidance/supervision?

Behavioral and emotional disorders

1. Does the child exhibit behaviours that are not expected in certain social situations?
2. Does the child exhibit bizarre motoric behaviours that are harmful to self, siblings, and/or peers?
3. Does the child show truant behaviour in the classroom?
4. Does the child often pick up quarrels?

Specific Language Impairment

1. Does the child have delay in the development of expressive speech and language skills?
2. Is the child poor in understanding the meaning of language?
3. Does the child manifest difficulty in understanding in a noisy environment?
4. Does the child miss on the grammatical elements of speech?
5. Does the child show inconsistencies in pronunciation of speech sounds?

Dysarthria/Cerebral Palsy

1. Does the child experience difficulty in carrying out voluntary motor movements?
2. Does the child present with motor dysfunction?
3. Does the child present severe speech problems with motor incoordination?
4. Does the child manifest excessive motor movements/drooling/difficulty in chewing and sucking?

Mental retardation

1. Was the child slow in achieving the milestones of sitting, standing, walking and talking?
2. Does the child look dull and intellectually deficit?
3. Does the child have a history of seizures?

Autism and related disorders

1. Does the child exhibit little or no eye contact?

2. Does the child prefer to be alone?
3. Does the child exhibit inappropriate laughing and giggling?
4. Does the child exhibit apparent insensitivity to pain?
5. Does the child exhibit insistence on sameness or resists changes in routine?
6. Does the child have difficulty in communication?

Attention Deficit Hyperactivity Disorder/Attention Deficit Disorder

1. Does the child have difficulty in remaining seated?
2. Does the child often fidget with hands/feet or squirm in the seat?
3. Does the child have difficulty playing quietly?
4. Does the child often talk excessively?
5. Does the child often shift from one uncompleted activity to another?
6. Does the child have difficulty in sustaining attention to tasks or play activities?

APPENDIX 3

TASKS SUGGESTIVE OF ORAL AND VERBAL PRAXIS DEFICITS IN PERSONS WITH DOWN SYNDROME

I. ORAL PRAXIS ASSESSMENT

A. ISOLATED ORAL MOVEMENTS

The child is asked to imitate the following movements.

Action	Accuracy	Rate	Repetitions	Score	% score
Tongue movement					
10. Stick out your tongue					
11. Lick your lips with tongue					
12. Touch the nose with tip of tongue					
13. Move your tongue in and out					
14. Move your tongue to the right					
15. Move your tongue to the left					
16. Click your tongue					
17. Wiggle your tongue from side to side					
Total score					
Others					
18. Clear your throat					
19. Puff up your cheeks					
Total score					

The accuracy and rate are evaluated based on the number of repetitions provided. All responses are scored based on rate, accuracy and cues used as follows:

4- Movement/action is accurate and rate is appropriate
3- Movement/action is accurate and rate is appropriate with one repetition
2- Either movement/action or rate is inappropriate with more than one repetition
1- Both are inappropriate with more than one repetition
0- Child is unable to perform even with repetitions

B. SEQUENTIAL ORAL MOVEMENTS

The child is asked to imitate the following sequential oral movements:

SNo.	Stimulus	Transcribed response	SMS
1	Bite and blow		
2	Smile and kiss		
3	Blow and smile		
4	Kiss and stick out your tongue		
5	Bite and open your mouth		

Scoring is done as follows:

Sequence maintenance score (SMS):
2- Completes both movements in the order stated (correct sequence)
1- Completes both movements in reverse order (incorrect sequence) or adds an extra movement, or repeats a movement
0- Completes only one movement or completes the same movement twice

II. VERBAL PRAXIS ASSESSMENT

A. SEQUENTIAL VERBAL MOVEMENTS

The child is asked to imitate the following sequential verbal utterances:

SNo.	Stimulus	Transcribed response	SMS
1	a-u		
2	o-i		
3	m-u		
4	a-m-u		
5	u-i-a		
6	i-u-a		
7	m-o-i		

Scoring is done as follows:

Sequence maintenance score (SMS):
2- Repeats all phonemes correctly
1- Repeats 2 out of 3 oromotor sequences correctly or repeats the oromotor phonemes 5 or 6 times
0- Repeats one out of 3 oromotor sequences correctly or repeats the oromotor phoneme sequence more than 6 times

If the child does not respond, write NR next to the column

B. ASSESSMENT OF DIADOCHOKINETIC (DDK) TASKS

The child is asked to repeat the stimuli 'pə', ṱə', 'kə' and 'pəṱəkə' as fast as possible. Time taken for completing at least 10 repetitions is calculated. Indicate the number of attempts needed to complete 10 iterations and whether sequence is maintained in the repetition of 'paṱaka'.

No.	Stimulus	Time taken for 10 iterations	DDK (it/sec)	Sequence for 4 repetitions	Number of attempts
1.	pə			-	
2.	ṱə				
3	kə				
4	pə-ṱə-kə				

Consistency of DDK task (pa-ta-ka):

Keeping the first pa-ta-ka utterance as reference, evaluate the consistency of the task as follows:

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

C. WORD LEVEL PRAXIS ASSESSMENT

The child is asked to repeat the following words after the investigator.

Target	Transcribed response	Phonological Errors			SMS
		SE	TE	WWE	
tale					
si:re					
məne					
se:bu					
na:ji					
bekku					
pennu					
tʃ^{h}ətri					
təʈʈe					
su:rja					
ba:gilu					
huɖugi					
kiʈəki					
tʃəmətʃa					
kudəlu					
ba:gilu					
da:ɭimbe					
pustəka					
tʃəppəli					
i:ruɭɭi					
ərəməne					
əɖigeməne					
ba:tʃəɳige					
gəɖija:ra					
ga:ɭipəʈa					
kənnəɖəka					
ba:ɭehəɳɳu					
de:vəst^{h}a:na					
a:lu:gəɖɖe					
teŋginəka:ji					
kriʃɳa					
driʃja					

Target	Transcribed response	Phonological Errors			SMS
		SE	TE	WWE	
prəʃne					
swətʃtʃ^{h}a					
vaidja					
vjəvəst^{h}e					
pra:t^{h}əmika					
brəmhərʃi					
svərgəst^{h}a					
prəkʃubd^{h}a					
Total scores					

The errors are transcribed and total number of errors is counted. A score of ' 1 ' is given for each error.

Key for scoring errors:

Space errors (SE): fronting, backing, palatalization, depalatalization, and vowel deviations including vowel prolongation, vowel shortening, vowel centralization, vowel decentralization, monophthongization, diphthongization, vowel raising and vowel lowering.

Timing errors (TE): voicing errors, affrication, deaffrication, denasalization, gemination and degemination.

Whole word errors (WWE): cluster reduction, reduplication, consonant harmony, migration, metathesis, epenthesis, initial consonant deletion, medial consonant deletion; and initial, medial and final syllable deletions

Sequence maintenance score (SMS): *Disyllabic words*

2- Repeats both syllables in the correct order

1- Repeats both syllables in reverse order or repeats a syllable or adds/deletes a syllable

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

If the child does not respond, mark NR and score 0

Sequence maintenance score: *Trisyllabic and multisyllabic words*

2- Repeats all syllables in the correct sequence

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

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

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

Note: Do not penalize the child for consonant/vowel substitution unless where consonant/vowel harmony and cluster reduction occurs as repetition of syllables takes place

D. SENTENCE LEVEL ASSESSMENT

The child is asked to repeat the following sentences after the investigator.

Target	Transcribed response	SMS
illi ba		
ədu məra		
na:n bərijəlla		
nənge ʤvəra idɛ		
a karu hogta idɛ		
sku:ləlli ʧənna:g o:dbeku		
məisu:rəlli ərməne idɛ		
gaɭipəʈa məgu kəijəllidɛ		
nəmənɳa ka:fi kuɖita iddare		
nenne əmma nənge məisur pa:k ma:ɖkoʈru		

Sequence maintenance score

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

1 - Sentences with < 3 words- At least 1 word is in order
Sentences with > 3 words-At least 3 of the key words are in order

0- Sentences with < 3 words- 0 words in order
Sentences with > 3 words- 2, 1 or no key words are in order

E. ANALYSIS OF SPONTANEOUS SPEECH SAMPLE

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

Transcribed sample:

Phonotactic analysis: Calculate the different types of syllables (V, CV, VC, CVC), words (mono-, di-, tri-, multi-syllabic) and clusters (initial, medial geminate, medial non-geminate, medial three-sound, final) from the words to calculate their percentage occurrences.

Percentage occurrences of different types of syllables

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

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

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

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

Percentage occurrences of different types of words

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

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

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

$$\frac{\text{Number of multisyllabic words}}{\text{Total number of words}} \text{ X } 100 = \% \text{ multisyllabic words}$$

Percentage occurrences of different types of clusters

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

$$\frac{\text{Number of medial geminate clusters}}{\text{Total number of words}} \text{ X } 100 = \% \text{ medial geminate clusters}$$

$$\frac{\text{Number of medial non-geminate clusters}}{\text{Total number of words}} \text{ X } 100 = \% \text{ medial non-geminate clusters}$$

$$\frac{\text{Number of medial three-sound clusters}}{\text{Total number of words}} \text{ X } 100 = \% \text{ medial three-sound clusters}$$

$$\frac{\text{Number of final clusters}}{\text{Total number of words}} \text{ X } 100 - \% \text{ final clusters}$$

II. ORAL PRAXIS ASSESSMENT

A. ISOLATED ORAL MOVEMENTS

The child is asked to imitate the following movements.

Action	Accuracy	Rate	Repetitions	Score
Jaw movement				
1. Click teeth together once				
2. Open your mouth				
3. Close your mouth				
4. Hold your mouth open at midrange				
Lip movement				
5. Smile				
6. Pucker lips				
7. Bite lower lip				
8. Blow				
9. Pretend to kiss				
Tongue movement				
10. Stick out your tongue				
11. Lick your lips with tongue				
12. Touch the nose with tip of tongue				
13. Move your tongue in and out				
14. Move your tongue to the right				
15. Move your tongue to the left				
16. Click your tongue				
17. Wiggle your tongue from side to side				
Others				
18. Clear your throat				
19. Puff up your cheeks				

The accuracy and rate are evaluated based on the number of repetitions provided. All responses are scored based on rate, accuracy and cues used as follows:

4- Movement/action is accurate and rate is appropriate
3- Movement/action is accurate and rate is appropriate with one repetition
2- Either movement/action or rate is inappropriate with more than one repetition
1- Both are inappropriate with more than one repetition
0- Child is unable to perform even with repetitions

B. SEQUENTIAL ORAL MOVEMENTS

The child is asked to imitate the following sequential oral movements:

SNo.	Stimulus	Transcribed response	MCS	SMS
1	Bite and blow			
2	Smile and kiss			
3	Blow and smile			
4	Kiss and stick out your tongue			
5	Bite and open your mouth			

Two types of scores are given as follows: .

Motor control score (MCS):
2- Both movements are precise
1- One of the movements is imprecise
0- Both movements are imprecise

Sequence maintenance score (SMS):
2- Completes both movements in the order stated (correct sequence)
1- Completes both movements in reverse order (incorrect sequence) or adds an extra movement
0- Completes only one movement or completes the same movement twice

III. VERBAL PRAXIS ASSESSMENT

A. ISOLATED VERBAL MOVEMENTS

The child is asked to imitate the following syllables, consonants and vowels.

Action	Accuracy	Repetitions	Score
Jaw movement			
1. Open your mouth and say 'ahh'			
2. Close your mouth and say 'm…'			
3. Say /jə/			
4. Say /əi/			
5. Say /əu/			
Lip movement			
6. Say /pə/.			
7. Say /o/			
8. Say /u/			
9. Say/i/			
10. Say/e/			