MOTOR SPEECH CHARACTERISTICS IN 4-10 YEAR OLD TYPICALLY DEVELOPING KANNADA SPEAKING CHILDREN

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Register No. 13SLP005

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI

MYSURU- 570 006

May, 2015

CERTIFICATE

This is to certify that this dissertation entitled "***Motor speech characteristics in 4-10 year old typically developing Kannada speaking children***" is a bonafide work in part fulfillment for the degree of Master of Sciences (Speech-Language Pathology) of the student (Registration No. 13SLP006). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "***Motor speech characteristics in 4-10 year old typically developing Kannada speaking children***" is the result of my own study under the guidance of Dr. Jayakumar. T., Lecturer in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru

May, 2015

Registration No.: 13SLP005

Dedicated to

Appa & Amma

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CHAPTER 1

INTRODUCTION

Speech is a unique, dynamic and complex motor activity through which we express our thoughts, emotions and control our environment. It is a clear evidence for the complex motor control in human. It is the most powerful tools possessed by humans and the degree to which we use it effectively contributes to the character and quality of liveliness. Speech is a learnt behaviour. It begins from birth and continues to develop till puberty. During this time, complex connections are established between the language and the motor centres in the developing brain. The maturation of these complex connections leads to the changes in the early non-speech sound production into a more controlled purposeful speech at the articulatory level.

Speech motor control refers to the systems and strategies that control the production of speech. It is believed that the input to the system of speech motor control is a phonologic representation of language and the output is a series of articulatory movements that convey the intended linguistic message through an acoustic signal that can be interpreted by a listener. Therefore, the process of speech motor control interacts between those of language formulation and that of the acoustic signal by which the speaker’s message is conveyed.

The acquisition of speech motor control is a gradual process for children between birth and puberty. The achievement of adult speech motor control is dependent on maturation of the individual's nervous system. During the first 24 months of life, musculoskeletal growth and neural maturation are critical components to the integration of the motor, sensory, and auditory systems which are necessary for the speech development. During this period, the child becomes familiar with the various movement parameters of the peripheral speech mechanism. During the next 6-10 years of life, there is gradual refinement of many temporal features of speech production (Kent, 1976). Studies on the movement parameters of individual components (Watkin & Fromm, 1984; Sharkey & Folkins, 1985) and acoustic parameters (Tingley & Allen, 1975; Kent & Forner, 1980) have implied that the variability in the performance of motor speech tasks is comparatively more in children than in adults. According to Robbins & Klee (1987) the temporospatial coordination of the individual components of the speech production mechanism may continue to improve until a particular control of articulatory movements is achieved at approximately eleven years of age.

Because preadolescent children exhibit speech motor control that is unlike that of adults, the use of adult standards or norms in the clinical evaluation of children's speech and oral motor control is incompatible. Children's ability to carry out various speech and non-speech motor tasks, and the variability in the execution of such tasks, forbids the use of adult-based standards with children.

Though there are normative exists in the literature, the information does not address the entire paediatric age span. Speech motor character is an important clinical problem because of which a clear understanding of normal speech is essential for the interpretation of disordered speech that may arise from hearing impairment and various neurological and developmental disorders. In general, studies regarding typically developing children have shown that accuracy in DDK tasks improved with age (Fletcher, 1972; Williams & Stackhouse, 2000). This suggests that this aspect of

DDK is a sensitive measure that can be applied in finding children who are atypically developing in motor speech skills, at least for some age groups.

The earlier studies of speech development were based on perceptual methods; one or more examiners transcribed the speech of child participants (Vihman, 1996). As the age advances, speech changes in its precision, fluency, voice quality, and communicative effectiveness (Weismer & Liss, 1991; Linville, 1996; Wohlert & Smith, 1998). The studies that have done earlier have mainly focussed on older children and adults. Merely a few works have been specifically aimed to examine the rate in normally developing young children. These studies have shown that as chronological age increases, diadochokinetic ability increases until about the age of eighteen. Also, many other important parameters of speech development also have shown a developing trend.

In a study by Williams and Stackhouse (2000), researchers found that consistency of speech production improved from a group of 3-year-olds to a group of 4-year olds. Many of the typically developing children in the 3-year-old had at least one inconsistent response involving minor motor speech movements, but such inconsistencies decreased with age. By age 4, most children were giving both accurate and consistent responses. This observation is a useful finding for clinical practice, because it can suggest the nature of a child's speech disorder. Therefore, inconsistency in DDK tasks may assist in diagnosing more inclusive speech processing problems.

Few other parameters that can be clearly used as a measure of developmental changes include; Second formant transition, where it is an important aspect of coarticulation. Various authors have suggested that there are changes that are taking place in the F2 value with age. Voice characteristics are another important aspect of maturation. As there are various anatomical changes that are taking place in the subsystems of voice production, various acoustic measures like fundamental frequency, intensity and perturbation measures are very important aspects to be studies as the acoustic measures are the reflection of the changing physiological system.

Intonation stimulability is a significant factor of speech motor control. It reflects the stability and the flexibility of the system to produce rapid changes in the acoustic aspects like frequency, intensity etc. Various investigations on prosodic development have suggested that major changes in the acquisition of intonation co-occur with the developments in grammatical development (Snow & Balog 2002; Snow 2000; Snow 2006).

Speech rate is an essential aspect of speech timing control in children. The rate of utterance in connected speech has implication both for the understanding of normal development of motor speech timing control and for the identification and management of timing differences in disordered speech (Kent, 1984; Yorkston, Beukelman, & Bell, 1988).

Systematic and objective studies on these aspects of speech motor control are very important for understanding the typical and atypical developmental patterns in children. Literature search reveals that the studies carried out on motor speech profiling of typically developing children is limited in Indian population. This may be due, in part, to a historical lack of reliable instruments and subjective methodology. The recent availability of computer-based tools has provided an opportunity to measure motor speech skills in children in an objective fashion. These tools have been used to study normal and disordered speech in adults, but limited information is available about using these tools to study motor speech characteristics in children.

To date, normative values for Motor Speech Profile (MSP) for children aged 4–10 years in Indian population has not been published. Identification, diagnosis and therapeutic managements of motor speech disordered population majorly occur in the age range of four to twelve years, so there is a definite demand for a normative database in Indian population.

Aim of the study

The aim of the present study is to determine the normative data for speech motor characteristics in 4-10 year old typically developing Kannada speaking children and to compare across age and gender.

Objectives

1. To establish normative data for speech motor characteristics in children aged 4–10 years (paediatric population).
    - To develop normative values for Diadochokinetic task.
    - To develop normative values and patterns for Second formant transitions.
    - To develop normative values for voice and tremor parameters.
    - To develop normative values for Intonation stimulability.
    - To develop normative values for syllabic rate.
2. To compare the parameters of motor speech profile across age and gender in paediatric population.

CHAPTER 2

REVIEW OF LITERATURE

Speech is the primary mode of human communication. It is the means by which discretely specified linguistic messages are converted to an acoustic signal that can be understood by a listener. Speech production is arguably the most complicated motor acts executed by human beings.

The basic components of speech production involve respiration, phonation, resonance, voice and speech. The fluctuations in the pressure and flow produce the acoustic signal that we hear when we listen to spoken communication. For this signal to be structured in such a way that it can transmitted into linguistic information, the elements of the vocal tract must be controlled and coordinated. Like any other skilled movement, the production of speech requires coordination of several subsystems like the respiratory, phonatory and different part of the vocal tract.

The resulting speech is laid over by the prosodic elements of intonation, stress and rhythm which are channelled by the changes in fundamental frequency (F0), temporal and intensity variables. The prosodic changes are the outcome of interplay between the different subsystems of speech production.

The process of speech is realized by the complex and purposive articulatory movements of the speech organs, for generating acoustic signals. It requires more motor fibres than any other human mechanical activity (Fink, 1986).The articulatory movements for the production of speech are solely under neuromuscular control. The motor patterns of speech speculate the co-ordinated function of the Central Nervous System (CNS).

Development of speech motor control

Motor development involves several distinct sequences of stages which involves differentiation (modification of a pre-existing behavior into more specialized one) and integration (consolidation of previously stabilized behaviors with a new one). In between these two stages is a period in which mature forms undergo continual refinement. It is probable that the organization of coordination for speech involves refinement and the integration and differentiation of vocal tract components, with each sequence having a distinct effect on the child's sound-producing capabilities (Fentress, 1984; Kent, 1992; Lenneberg, 1967).

Changes in speech production occur throughout the lifespan as a result of changes in the speech and language processing system, including modifications in the anatomy, physiology, sensory feedback, motor control, and central processing of speech (Kahane, 1981; Liss, Weismer, & Rosenbek, 1990; Lowit, Brendel, Dobinson, & Howell, 2006; Torre & Barlow, 2009).

The development of the nervous system follows a sequence of morphological events which is in proportion with the child's neurologic integrity as well as specific sensory and motor functions. One of the examples for such a sequence is that babbling anticipates important aspects of spoken language (Vihman 1996; de Boysson-Bardies 1999).

Till first 2 years of life, the critical components to the integration of the sensory, motor and auditory systems essential for speech development are the musculoskeletal growth and neural maturation. During this period, the child becomes familiar with the various movement parameters of the speech mechanism. From the age of 6-10 years of life, there is gradual refinement of various temporal variables of speech production (Kent, 1976).

From the various investigations done in the past indicated that there was a reduction in the variability in the speech motor system parameters with maturation (Walsh & Smith, 2002; Smith & Zelaznik, 2004). The variability seen in the developing motor system is an indication of a system acquiring new patterns of behavior (Thelen & Smith, 1994).

Various researchers have reported that there are gender differences in speech motor performance in preschoolers. It was found that girls execute a faster rate of speech compared to boys, but there are no evidences of differences in craniofacial growth pattern at this (Voperian et al., 2005). Smith (2010) claims that adults execute faster rate of speech than that of children by making smaller displacements of lips and jaw.

The temporal course and eventual acquisition of adult speech motor control are dependent on the individual's nervous system maturation (Yakovlev, 1962). According to researchers (Capture, Accardo, Vining, Rubenstein & Harryman, 1978) few factors that affect the neural maturation are myelination, axonal-dendritic growth, nerve cell proliferation and synaptogenesis. These factors show more changes during critical or sensitive period of the child's development.

Critical and Sensitive periods:

The concept of critical periods indicates finite items, in which specific events must occur to provide the substrate for subsequent developmental achievements. This *now-or-never* hypothesis is based on researches of sensorimotor development leading to cognitive maturation in children. The concept of sensitive periods has been proposed referring to periods when a child learns particular skills more easily than others. It is the time during an individual's life span when it is more sensitive to environmental stimulations than at other times during its lifetime.

Speech motor age

Speech motor age refers to the month wise representation of a child's acquisition of various speech motor acts. Picture 1 shows the developmental chart of speech motor skills developed by Netsell (1979) which describes the age at which an individual's functional components (respiratory, laryngeal, velopharyngeal, jaw, tongue and lip function) are developed based on the child's performance of selected speech motor acts.

A more complete speech motor age chart would extend to about 14 years and a long term could be to include speech motor acts that capture the essence of minimal change or development in both the speech emergence and speech refinement periods.

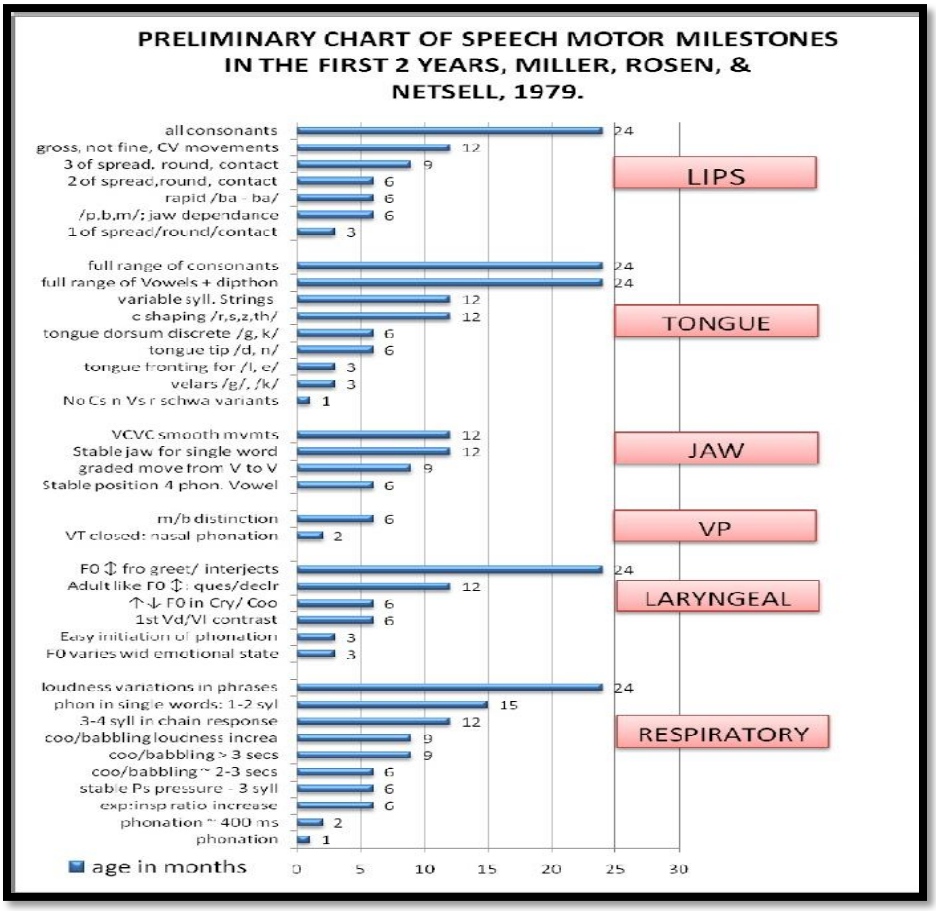


Figure 2.1: Speech motor milestones by Miller, Rosenbek & Netsell, 1979.

There have been many studies in the past by various researchers (Bruner, 1973; Kent & Moll, 1975; Smith,1978) which use a motor apprach to examine the development of ability to produce a given perceptual output in children.the minimal changes in speech motor patterns can be captured through varipous speech acts. Few commonly used speech motor measures are Diadichokinetic rate (DDK), F2 transition, Voice and tremor parameters, syllabic rate and intonation stimulability.Further, few relevant studies related to each of the parameter will be discussed under each heading.

Diadochokinetic rate (DDK)

Diadochokinetic rate (DDK) refers to an assessment tool, used by speech-language pathologists (SLPs), to assess the speech motor skills of children and is measured as how quickly an individual can accurately produce a series of rapid, alternating sounds such as /pa/ or /pataka/ (Fletcher, 1972). It is also known as maximum repetition rate and The Fletcher Time-by-Count Test of Diadochokinetic Syllable Rate. It is evaluated either in terms of the number of iterations per second or in the time required to produce number of iterations for the production of mono-, bi-, and trisyllabic tokens using a kind of consonant and vowel combinations (e.g., /pa/). Normative data for DDK has been established by various researchers for children (Robbins & Klee, 1987) and adults (Fletcher, 1972).

DDK analysis can be hand-measured or automatic. Literature describes few studies using hand measurement for counting the number of sequences produced by an individual. Measurements using an automatic DDK rate analyzer provides greater efficiency on the results .The Motor Speech Profile (MSP) model 5141 manufactured by KayPentax used in conjunction with Computerized Speech Lab (CSL) provides the opportunity of obtaining information such as average DDK period, rate and peak intensity, and other different measures.

The outcome of various researches have indicated that as the motor systems of children mature the DDK rates were also found to be increasing (Kent et al., 1987; Henry, 1990), and by 9-10 years adult like rates are achieved (Canning & Rose, 1974) or by age 15 (Fletcher, 1972). Studies have also shown that DDK rates are highly variable, both within and between participants, in which higher variability apparent for the younger age groups (Canning & Rose, 1974; Robbins & Klee, 1987;

Williams& Stackhouse, 2000). Various authors have documented that articulator movement variability is greater in children than adults (Sharkey & Folkins 1985; Smith & McLean-Muse, 1986; ; Smith & Goffman 1998; Goffman & Smith, 1999; Green et al., 2002;Grigos, Saxman, & Gordon, 2005). Although the emergence of speech sounds appears to be complete by approximately 8 years of age (Sanders, 1972), physiologic findings indicate that oromotor coordination (i.e., lip and jaw movement) remains more variable for this age group than for young adults at 14 years of age (Smith & Zelaznik, 2004). This finding suggests that maturation of speech motor control continues to develop throughout adolescence. Although coordination between the lips was shown to be more variable in children 14 years of age than in adults, a plateau in performance was observed between 7 and 12 years of age (Smith & Zelaznik, 2004).

Williams & Stackhouse (1998) studied DDK skills in normal and atypical performance of children in the age range of 3-5 years. Thirty typically developing children in the age range of 3-5 years were divided into three subgroups (3, 4 & 5 years) consisting of 10 subjects in each group. Children were asked to repeat a syllable sequence /pataka/ as quickly and accurately as possible. Results indicated that there is a significant improvement in the accuracy of production with age. In terms of rate, there was no significant developmental trend noticed. The consistency of productions improved significantly for children in the age range of 3 and 4 years.

Another study done by Yarrus and Logan (2002) aimed to evaluate the rate, accuracy, and consistency of repetitions of children's DDK aged between 3 and 7 years. 15 boys were taken as the subjects for the study. They were instructed to produce the sequence /pataka/ or ‘pattycake’. Findings of the present study have revealed that there was a significant relation between age and overall DDK rate.

Prathanee, Thanaviratananich & Pongjanyakul (2003) studied the oral DDK rates for normal Thai children between the age range of 6 and 13. The participants of the study were 197 children who were instructed to produce repetitions of 20 monosyllabic (/pa/, /ta/, /la/, /ka/), 15 bisyllabic (/pata/, /paka/) and 10 trisyllabic (/pataka/) utterances. Analysis was done using the software Visi Pitch The findings of the study revealed that the average rate for p/ was 4.55 , for /ta/, /la/, /ka/ was 4.58, 4.82, 4.85 and 5.87 seconds /pa-ta/, /pa-ka/ and /pa-ta-ka/ were 6.97, 7.52 and 6.85 seconds, respectively. There was age and gender influences on oral DDK time. Differences among boys and girls were significant for /pa/, /ta/, /ka. Boys tended to be faster than girls. However gender effect was not consistent across the research.

According to a study done by Castro and Wertzner (2011) on oral DDK using the software MSP in typically developing Brazilian Portuguese speaking children in the age range of 8-10 year old indicated that the mean number of syllables per second ranged from 4.8 to 5.2 for the syllable /pa/, between 4.9 and 5.4 for 'ta/ and between 4.3 and 4.9 for /ka/.

Second formant transition (F2 transition)

Second formant transition is defined as the change in frequency of the second formant from the onset of the vowel to a point in time 120 msec after the onset of the vowel. The boundary of the vowel is taken to be the onset of full glottal vibration, which is seen spectrographically as regularly spaced vertical striations.

The direction, the extent, and the duration of second formant transitions have been shown to be important in the correct perception of adjacent consonants (Sharf & Hemeyer, 1972). Some of the evidence from previous research on typical speech development suggests that the amount of gestural overlap in speech changes with age (Ziegler & Maassen, 2007).

Speech motor control development in children was studied by Hardcastle (2011) using ultrasound. The study was aimed to compare the coarticulatory properties of lingual sounds in children and adults using ultrasound imaging. Ten adults and ten children (6-9 years) Scottish English speakers were enrolled as participants for the study. To quantify coarticulation, distance between tongue curves were utilized. Results indicated that vowel pairs /a/-/u/ and /a/-/i/ significantly affected the consonant, but the pair /i/-/u/ did not. It was found that children exhibited greater extend of coarticulation when compared to adults suggesting that children's operates larger units for speech production than adults. Also greater within-speaker variability was noticed in the children than in the adults.

Another study done by Turnbaugh, Hoffman, Daniloff & Absher (1985) and Nittrouer (1985), has found that children seem to coarticulate more than adults indicating a higher magnitude and slower rate of F2 transition in younger age groups. In both the studies, second formant values were lowered in children's speech compared to adult speech.

Voice and tremor

Studies regarding the anatomy of the larynx have found that between birth and puberty marked changes took place in the laryngeal structures. During this period, the entire length and the ratio of the cartilaginous and membranous parts are varying during early childhood there are dramatic changes in the internal structures of the vocal folds. The total length of the vocal folds in a newborn baby has been measured to be between 2.5 and 8 mm (Aronson 1980; Hirano, Kurita & Nakashima 1983) From the researches (Crelin, 1973; Kahane, 1982) that was conducted earlier had found that the vocal folds of 4 year olds consist of a thicker layer of mucous and immature vocal ligament when compared to that of adults. The lamina propria is not differentiated into intermediate and deep layers (collagenous and elastic fibres) until the age of 23. All these anatomical changes in the laryngeal structures lead to differences in changes in the mechanical attributes also.

It is found that all the acoustic analysis is done on the premise that the acoustic measures represent the underlying physiology. The newborn infant has a fundamental frequency between 400-600 Hz during crying (Michelsson, Michelsson 1999). There is a rather rapid decrease in mean fundamental frequency (F0) for both boys and girls during the first three years of life (Titze, 2000). After that there is a more gradual decrease, until puberty when the mutational voice change occurs. In terms of gender differences, studies have indicated that both girls and boys adopt gender-specific articulatory and vocal behaviours from early childhood in order to enhance gender distinctions. Sergeant et al (2005) perceptually evaluated untrained singing voices of 29 children. Singing teachers were instructed to identify the gender of the sample voices. Results indicated that teachers were able to correctly identify the gender of the child as young as 4 years of age. Perry et al. (2001) similarly found that listeners were able to identify gender from the speech and voice of children from the age of 4 years and the gender ratings were made by the listeners based on vowel formant frequencies. Sergeant et al (2005) observed that the accuracy of gender identification increased with age in boys, whereas, an age effect was not seen in case of girls. This finding suggests that there are evident prepubertal changes that are taking place in boys while it is not apparent in girls. Voice source characteristics are another domain which has a difference between boys and girls (White, 1998). In a group of 11-year-olds, subglottal pressure and flow amplitude were both greater in boys, and boys also demonstrated a greater amount of glottal air leakage during vocal fold closure.

Correlating with the anatomical basis, information regarding the acoustic aspects has shown differences in important voice parameters like fundamental frequency between children and adults well s between males and females (Nicolas, 2007; Ting et al, 2011). The measurement of these acoustic variables will assist in providing the normal development as well as helps in the diagnosis and management of different voice disorders. Various authors have suggested that information regarding signal to noise ratio, jitter and shimmer can provide more information that is clinically relevant.

The acoustic characteristics of children were studied by Glaze, Bless, Milenkovic and Susser (1988). He investigated the 4 voice parameters such as Fundamental frequency, SNR, jitter and shimmer to study the relationship between children's age, gender, height, and weight. Participants of the study were 121 normal children between the age range of 5-11 years. The task given was to phonate the vowel /o/ continuously. The mean F0 of males and females were 226 Hz and 238 Hz respectively. The findings of the present study indicated that there is a statistically significant positive correlation between frequency and gender where girls exhibited higher frequency compared to males.

Another study was done by Nicollas, Garrel, Ouaknine, Giovanni, Nazarian and Triglia (2007) to establish the normative database of children in the age range of 6 and 12 years. The participants of the study were two hundred twelve children who consisted of 111 females and 101 males. The acoustic analysis was carried out using Diana software. From each sample, Fundamental frequency (Fo), shimmer, and jitter were obtained. Results suggested that there was a decrement in the Fundamental frequency (Fo) with age and was lower in boys when compared to girls. Jitter and shimmer values were also found to be decreasing with age, though it was not significant.

Ting, Chia, Manap, Ho, Tiu, Hamid and Lumpur (2011) aimed to study the fundamental frequency (F0) and perturbation measures in 360 Malaysian children in the age range of 7 to 12 years. Acoustic analysis using Praat software was done for sustained vowels. It was found that there were no significant differences in F0 across the Malay vowels for both males and females. The mean F0 of Malay females were significantly higher when compared to males. There was a significant difference in F0 that was noticed across age groups. Overall no significant difference was noticed for perturbation measures across age and gender.

Normative acoustic values of Turkish speaking children in the age range of 4 to 14 years were established by Akmese, Kayikci and Atas (2012). Subjects were instructed to phonate /a/ continuously and were analyzed using MDVP software. Results of the study indicated that significant difference in Fundamental frequency between genders started from the age of 8 in males and after 10 years in females.

Intonation

Speech prosody involves the ‘‘musical’’ aspects of language, i.e, variations in the pitch, length and loudness of spoken utterances. One of the subsystems of prosody is intonation, or speech melody, which refers to the linguistic use of pitch patterns on the level of phrases, clauses, and sentences.

It refers to distinctive patterns of vocal melody (Crystal, 1991; Cruttenden, 1997). On the acoustic level, melody patterns result from changes in the fundamental frequency (F0) of the voice. Finally, on the psychological level, “tone” refers to the functional organization of pitch patterns in the phonological system of speakers and listeners.

Accent range or pitch change is an important aspect of intonation. This is the difference between the highest and lowest points in the fundamental frequency contour. Pitch change measures in a study done by Snow (2002) has demonstrated that children younger than 18 months does not use intonation in the same way 4-year old children uses.

Recent research has indicated that intonation is an early developing system. Various investigations on prosodic development have suggested that major changes in the acquisition of intonation co-occur with the developments in grammatical development (Snow & Balog 2002; Snow 2000; Snow 2006). Other researchers have found out that advances in intonation overlap with the onset of pragmatics (Bates, Camaioni, & Volterra, 1975)

It is suggested that children master most or all of the intonation system before they produce their first words (Bever, Fodor, & Weksel, 1971). Recent studies on the acquisition of Dutch and European Portuguese intonational patterns have found that its development is correlated with an increase in vocabulary size (Chen & Fikkert 2007, Frota & Vigário 2008). DePaolis, Vihman & Kunnari (2008) found evidence for more adult like F0 patterns and duration roughly at the same developmental. In production, young children seem to show a more accurate control of intonation earlier than duration (Snow, 1994, Prieto et al 2012).

Research suggests that one area where skills continue to develop through the school years is intonation. According to Local (1980) during the course of the children's sixth year, there was a highly significant increase in number of words per tone unit over the period studied.

The difference between boys and girls in relative frequency of rises indicates that there may be intonational differences within a group of children of the same age, differences that may be related to factors other than age like gender.

Weinberg & Bennet (1971) studied the mean speaking F0 of children in the age range of 6-7years. Spontaneous speech samples of the subjects were taken. The results showed that the mean value of F0 for males and females were 235.59 Hz and 251.6 Hz.

Mcglone & Mcglone (1972) conducted a study to investigate the speaking fundamental frequency of 8 year old girls. Reading samples were taken from eight participants. The findings of the study revealed that the mean F0 of girls was 248.8 Hz.

Bennet (1983) has studied the speaking F0 of children in the age range of 8-11 years. Results indicated that the mean SF0 was 224 Hz and 226 Hz for males and females. No significant difference between males and females were observed.

Wheat and Hudson (1988) established the normative data for speaking fundamental frequency of 6 year old males and females. The results indicated that mean sF0 of males and females were 219 Hz and 211 Hz respectively.

Another study was conducted by Sorenson (1989) in 6-10 years old children (Boys and girls). Spontaneous speech samples of all the subjects were recorded and analyzed. The results of the study indicated the mean F0 of boys and girls varied from 250 to 221 Hz and 296 to 229 Hz respectively. Thus the study suggested that there is a significant difference for speaking fundamental frequency across age and gender.

Ferrand & Bloom (1996) aimed of the study the intonational variables in children in the age range of 3-10 years. Conversational speech samples were recorded for analyzing parameters like mean F0, minimum and maximum F0 and the standard deviation of F0 and also to analyse the pattern of intonation. Findings indicated that the mean F0 of the males decreased at around age 7-8 years. Additionally, maximum F0, range, and percentage of rising and falling shifts all showed decreases for the males starting at ages 7-8 not paralleled by decreases for the females. It appears that around age 7-8 males begin to restrict their intonational ranges, while females maintain similar patterns across age groups.

Research was conducted by Wells & Peppe (2004) to study the intonation development in 5-13 years. Results indicate that there is considerable variability among children within each age band on most tasks. Studies have indicated that the ability to produce intonation functionally is established by five year olds though finer functional aspects are not mastered until 8-9 years. Intonation comprehension continues to develop till 10.9 years.

Speech rate

Acoustic temporal measures of speech production are part of the developmental study of speech timing control in children. The rate of utterance in connected speech has significance both for the understanding of normal development of motor speech timing control and for the identification and management of timing differences in disordered speech (Kent, 1984; Yorkston, Beukelman, & Bell, 1988). Normative data on speech rate form an essential baseline for the identification and diagnosis of deviations in rate, for the planning of management strategies, and for treatment outcome measures. A number of variables have been found to interact with speech rate. For example, linguistic and cognitive variables have included syntactic complexity complexity (Cook, Smith, & Lalljee, 1974; Hawkins, 1971), utterance length (Malecot, Johnston, & Kizziar, 1972), age (Duchin & Mysak, 1987; Malecot et al., 1972; Ryan, 1972; Smith, Wasowicz, & Preston, 1987) and speaking context (Duchin & Mysak, 1987; Fonagy & Magdics, 1960; Goldman-Eisler, 1956). According to Scherz-Schade (2004) speaking rate is influenced by five factors such as articulation rate, pause duration, speaking rate, length of the articulatory phrase and percentage of pause time.

Kowal, O'Connell & Sabin (1975) observed an increase of the mean rate of spontaneous speech from roughly two syllables per second at the age of 6 years, to four syllables per second at 14 years. Research on utterance rate in children, mostly with children 5 years of age or older, has shown a comparable developmental trend (Amster, 1985). Most of the studies have proved a considerable individual variability, especially in segment duration (Miller, Grosjean & Lomanto, 1984; Shewan & Henderson, 1988). It was also found that duration of speech segments is greater and more variable in young children than in older children and adults (DiSimoni, 1974a, 1974b, 1974c; Gilbert & Purves, 1977; Tingley & Allen, 1975) and the rate tends to increase with age (Kelly, 1994; Kent & Forner, 1980; Kowal, O' Connel & Sabin, 1975; Walker, Archibald, Cherniak & Fish, 1992). Other studies have suggested that reduction in the segmental duration (Kubaksha & Keating, 1981; Nittrouer, 1993; Robb & Saxman, 1990 & Iverson, 2010). Another study on children’s speech production is that children below 6 years have longer speech segment durations than adults and older children (Subtenly, Worth & Sakuda, 1966; Hawkins, 1973). In contradicting to this other authors have found out that there is an increase in syllable durations with development (Boysson- Bardies, Bacri, sagart & Poizart, 1981). In certain studies it is reported that the speech rate of girls are faster when compared to that of boys until the age of 12 (Dawson, 1929)

Walker et al (1992) provided normative data on articulation rate in preschool children and to examine the influence on articulation rate of age, gender, context, and utterance length in children aged between 3 and 5 years. Speech samples were obtained in spontaneous and imitative speaking contexts. The spontaneous speech sample was elicited with a story-telling task. Results of this study demonstrate a developmental trend of increased articulation rate with age. Speech rate has increased from 3.82 to 4.28 syllables /sec when 2-3 year group was compared with 5 year olds. Thus indicating the articulation rate of the 5-year-old subjects was significantly faster than that of the 3-year-olds. Spontaneous speech was significantly faster and more variable than imitated speech. No significant gender differences were found in mean articulation rates in spontaneous and imitated speaking contexts.

Ann (1982) studied the durational changes with variations in speech rate in children. She suggests that children's patterns of durational changes with rate changes provide a good index for the maturation of the speech motor control system. The participants were 2 groups of children of ages 3 and 7 years and one adult group. They were instructed to recite a sentence containing a /CVC/ word in 3 speech rates: normal, fast, slow. Parameters studied were vocal intensity, overall sentence duration, individual word and pause durations. The results indicated that overall sentence durations were approximately 500 msec longer than that for adults and contained much longer pause times.

Haswlager, Slis and Rietveld (1991) conducted a study to investigate the development of rate of speech in children in the age range of 5-11 years. Both DDK and spontaneous speech samples were collected. Results indicated that speech rate increases with age and is higher in long than in short utterances. Rate of spontaneous speech and the DDK rate were found to be weakly related. Also no significant gender was noticed for both the groups.

Studies related to Motor Speech Profile (MSP)

Wang, Kent, Duffy and Thomas (2008) studied the DDK rates in ataxic dysarthria. Twenty-one participants with ataxic dysarthria were recorded as they repeated various syllables as quickly and steadily as possible. The DDK samples were analyzed objectively as well as hand-measured. Analyses were based on the percentage of non executable DDK samples. Results revealed that more than one third of the DDK samples were non executable, the reliability at different thresholds and concurrent validity between different measuring methods(both objective and hand-measured) were both satisfactory, and the temporal variation parameters were more inconsistent between different measuring methods than intensity variation parameters.

Wong et al (2011) conducted a study to report the motor speech characteristics in healthy paediatric population. This was conducted in 112 subjects (54 females and 58 males) aged 4 to 18 years. Subjects were divided into 3 subgroups (4-8y, 9-13 y and 14-18y). Voice samples were recorded and analysed using the Motor Speech Profile (MSP) software. Results indicated that there was an increase in average diadochokinetic rate and standard syllabic duration with age. There were no identified differences in motor speech characteristics between males and females across the measured age range. The average DDK rate among children aged 4-18 years was 5.07 syllables/ second.DDK rate increased with age in both males and females. The magnitude of second formant transitions decreased with age and rate of F2 transitions (i.e. how quickly subjects could change from /i/ to /u/) increased with age. The parameters for intonation stimulability did not differ with age as well as gender. Standard syllabic rate increased slightly with increasing age in males and females but was not statistically significant.

John et al (2012) conducted a study to establish normative for Motor Speech Profile in Kannada Speaking adults. In their study, native Kannada speakers (n =300) were divided into three age groups (20–40, 41–50, and 51–60 years) with 50 males and 50 females in each group. The obtained data are reported across age and gender for the parameters of diadochokinetic rate, second formant transition, and voice and tremor characteristics of MSP software. The findings indicated that there was an overall age and gender effect for all the parameters.

Another study was conducted by Wertzner at al (2013) to study the oral motor skills in children with and without speech sound disorder. Subjects consisted of children in the age range of 5-7 years. DDK skills were assessed by the repetition of the sequences /pa/, /ta/, /ka/ and /pataka/ measured both manually and by the software Motor Speech Profile. Findings indicated that there was a significant age that was seen for the control group and gender effect was observed for both experimental and control group. Results presented strong agreement between the values of oral diadochokinesia measured manually and by MSP.

Eskader et al (2014) objectively analysed the motor speech performance in Children with Cochlear Implants. Participants were sixteen subjects (aged 8-17 years) using unilateral cochlear implants were studied. The speech samples were analyzed with the Motor Speech Profile (MSP) software. Results were compared to previously published normative paediatric data. Overall, subjects demonstrated excellent articulation and timing but poor frequency in intonation stimulability.

The normative data for adults in the age range of 20-60 years were developed by Manjula & Patil (2014) using MSP software. Subjects were divided into 4 age groups, 20-30, 30-40, 40-50 and 50-60 years. Results revealed that the DDK value had a significant age and gender effect. There was a significant gender effect observed for F2 transition. The mean Fo was found to be higher in females than in males. Significant age effect was found in females, not in males. Gender effect was significant for Fo. In intonation stimulability significant age effect was seen in females, but not in males. Gender effect was also significant. In syllabic rate there was no significant age or gender effect.

In summary, that there are various researches that have been carried out in order to document the various aspects of development of speech motor control in children as well as in adults in western population. An attempt has been made in the present study to objectively measure and establish the normative data for the speech motor characteristics in children aged between 4 to 10 years and to compare the values between males and females.

CHAPTER 3

METHOD

Participants

A total of 90 native Kannada speaking (Mysore dialect) typically developing children in the age range 4 to 10 years were participated in the study. The speech samples of children were collected from three different schools (1 Government. and 2 private schools). The participants were divided into 3 subgroups [4-6 years (mean age: 4.98), 6-8 years (mean age: 7.06) and 8-10 years (mean age: 8.85)]. Each subgroup consisted of 30 participants of fifteen male and fifteen females. The inclusion criteria of participants were, the subjects should be (a) native speakers of Kannada (b) no history of speech, language and hearing problem (c) normal oral structures and (d) no other associated psychological and neurological problems e) those children whose academic performance is very poor were excluded from the study.

Instrumentation

The Motor Speech Profile (MSP) Model 5141 module was used to measure the parameters for the study. It is an integrated software and hardware system from Computerized Speech Laboratory (CSL) Model 4500 (KayPENTAX, Lincoln Park, New Jersey). It provides a reproducible, non- invasive and objective method for assessing motor speech characteristics in subjects.

Procedure

Written consent was obtained from parents of each child through teachers. The samples were recorded in a silent room in the school. Before starting the sample recording, a standard instruction for each recording was given to the participants and before the test begins; two practice trials were given as a familiarization exercise.

Children were asked to listen to the recorded model sample of a native Kannada female speaker, specifically for each parameter. Three voice trials (tokens) were recorded for each voice task. The Olympus multi track linear PCM recorder (Model No: LS 100) was used for recording the samples. The recorder was kept approximately 10-15 centimeters away from the mouth of the participant.

Protocol for obtaining the data/ Speech recording

The MSP software offers the provision of analyzing five parameters: Diadochokinetic rate (DDK), second formant transition, voice and tremor parameters, intonation stimulability and syllabic rate.

1. Diadochokinetic Rate

The production of sustained syllables in DDK, requires the integrity of several speech musculatures that need to work in coordinated and unison manner. Under DDK, the software captures several aspects such as rate, average period, various measures of perturbations in period and intensity. In this task, children were instructed to produce multiple repetitions of /pa/, /ta/, /ka/ (Alternate Motion Rate) and /pataka/ (Simultaneous Motion Rate) separately as quickly as possible.

2. Second Formant Transition (F2 transition)

The F2 transition is an important measure of coarticulation. Under this parameter, various aspects of F2 magnitude, rate, and regularity are studied. Children were instructed to repeat /i-u/ as quickly, regularly and clearly as possible. As the F2 transition for children was not smooth as adults, analysis for this parameter was done without considering the band limit.

3. Voice and tremor parameter

Under voice and tremor parameters various measures of frequency, intensity and perturbation measures like jitter, shimmer etc. are captured. These parameters reflect the physiological variations in speech production with development. For this parameter the given task was to phonate the vowel /a/ for minimum 3 seconds after taking a deep breath.

4. Intonation stimulability

The intonation parameters addressed in the study includes various domains of Fundamental frequency range, variations in F0 and intensity during speech production. The stimulus sentence was a simple Kannada sentence 'amma ee hannu thumba chanagide'. The stimuli were of a native Kannada female speaker with speaking fundamental frequency (SF0) - 218, maximum pitch-359, minimum pitch-164 Children were instructed to imitate the model sample as much as possible.

5. Syllabic rate

This is an important aspect of development as reported by various researches. There are variations in the different variables of rate of speech with an increase in age. Parameters like syllabic rate, syllable duration, percentage speaking time, pause duration etc. are studied. The stimuli used for this task was a simple Kannada sentence 'naanu saayankaala manege hogtini'. The speaking fundamental frequency 224 and speaking duration of 2.31 seconds. Children were instructed to listen to the model sample and to repeat them at their comfortable rate.

Table 3.1: *Summary of the stimulus presented*

Sl. No	Parameters	Stimulus	Instruction
1.	Diadochokinesis (DDK)	AMR-/pa/, /ta/, /ka/	Repeat /pa/, /ta/ and /ka/or /pa, ta, ka/ seperately as quickly,

		SMR-/pa, ta, ka/	clearly as you can while you see my arms raised, when I lower my arm you can stop the repetitions.
2.	Second Formant Transitions(F2)	/i-u/	Repeat /i-u/ as quickly, regularly, clearly as possible
3.	Voice and tremor parameters	/a/	Take a deep breath and phonate /a/
4.	Intonation Stimulability	'amma ee hannu thumba chanagide'	Listen carefully to the model which will be presented through audio mode. Imitate the intonation of the passage as much as possible.
5.	Syllabic rate parameters	'naanu saayankaala manege hogtini'	Listen carefully to the model which will be presented through audio mode and repeat it at your own comfortable speaking rate

Table 3.2: *List of parameters measured under each group of measures*

Parameters		
Diadochokinetic rate related measures	**Symbol**	**Unit**
1) Average DDK Period	DDKavp	ms
2) Average DDK Rate	DDKavr	/s
3) Standard Deviation of DDK Period	DDKsdp	ms
4) Coefficient of Variation of DDK Period	DDKcvp	%
5) Perturbation of DDK Period	DDKjit	%
6) Average DDK Peak Intensity	DDKavi	dB

7) Standard Deviation of DDK Peak Intensity	DDKsdi	dB
8) Coefficient of Variation of DDK Peak Intensity	DDKcvi	%
9) Maximum Intensity of DDK Sample	DDKmxa	dB
10) Average Intensity of DDK Sample	DDKava	dB
11) Average Syllabic Intensity	DDKsla	dB
Second Formant Transition Parameters		
1) Magnitude of F2 variation	F2magn	Hz
2) Rate of F2 Variation	F2rate	/s
3) Regularity of F2 Variation	F2reg	%
4) Average of F2 Value	F2aver	Hz
5) Minimum F2 Value	F2min	Hz
6) Maximum F2 Value	F2max	Hz
Voice Parameters		
1) Average Fundamental Frequency	F0	Hz
2) Average Pitch Period	T0	ms
3) Highest Fundamental Frequency	Fhi	Hz
4) Lowest Fundamental Frequency	Flo	Hz
5) Standard Deviation of Fundamental Frequency	STD	Hz
6) Coefficient of Variation of Fundamental Frequency	vF0	%
7) Coefficient of Variation of Amplitude	vAm	%
Tremor Parameters		
1) Magnitude Frequency Tremor	Mftr	%

2) Magnitude Amplitude Tremor	Matr	%
3) Rate of Frequency Tremor	Rftr	Hz
4) Rate of Amplitude Tremor	Ratr	Hz
5) Periodicity of Frequency Tremor	Pftr	%
6) Periodicity of Amplitude Tremor	Patr	%
Intonation Stimulability Parameters		
1) Running Speech Fund. Frequency	rF0	Hz
2) Running Speech Pitch Period	rT0	ms
3) Highest Fundamental Frequency	rFhi	Hz
4) Lowest Fundamental Frequency	rFlo	Hz
5) Standard Deviation of Fundamental Frequency	rSTD	Hz
6) Frequency Variability	rvF0	%
7) Amplitude Variability	rvAm	%
Syllabic Rate Parameters		
1) Average Syllabic Rate	SLrate	/s
2) Average Syllabic Duration	SLsdur	ms
3) Average Pause Duration	SLpdur	ms
4) Percentage Speaking Time	SLspk	%
5) Percentage Pause Time	SLpau	%

Analysis

All the parameters were analyzed using MSP module. For the analysis of each parameter samples were loaded to the software. The analysis was carried out using 'MSP advanced' in the module. Under each parameter, the samples were selected and analysed for 3 seconds. The initial and final portions of the sample were excluded from analysis. The time window was kept as 3 seconds as to maintain uniformity in analysis across age group, as children in the younger age group will have a lesser Maximum Phonation Duration (MPD). MSP summarizes the numerical outcomes and presents them as a report so that changes over time can be more easily studied.

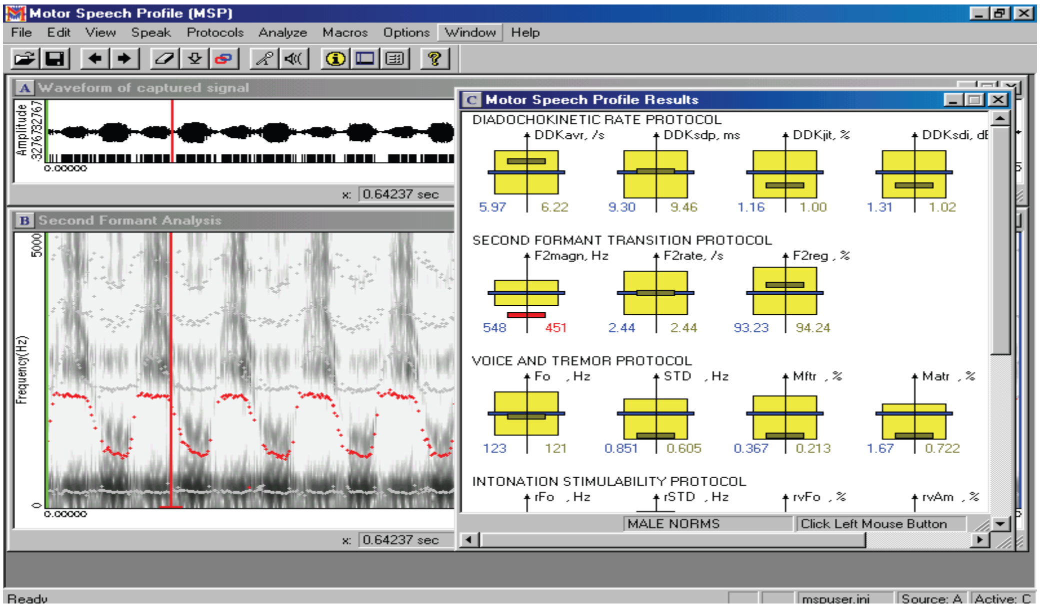
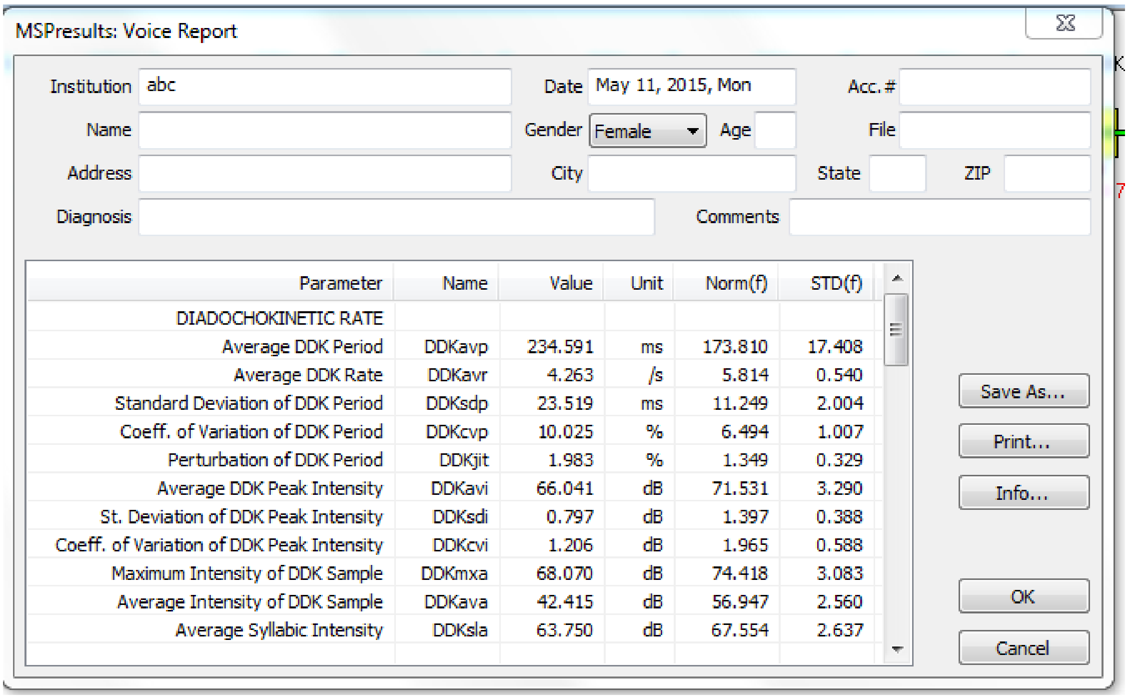


Fig 3.1: *Screenshot of MSP software for F2 transition*

This display helps the examiner to easily inspect the status of the client when compared to the norms. In the statistics table both subjects' values and the average norm is also represented.



MSPresults: Voice Report

Institution: abc | Date: May 11, 2015, Mon | Acc. #:
Name: | Gender: Female | Age: | File:
Address: | City: | State: | ZIP:
Diagnosis: | Comments:

Parameter	Name	Value	Unit	Norm(f)	STD(f)
DIADOCHOKINETIC RATE					
Average DDK Period	DDKavp	234.591	ms	173.810	17.408
Average DDK Rate	DDKavr	4.263	/s	5.814	0.540
Standard Deviation of DDK Period	DDKsdp	23.519	ms	11.249	2.004
Coeff. of Variation of DDK Period	DDKcvp	10.025	%	6.494	1.007
Perturbation of DDK Period	DDKjit	1.983	%	1.349	0.329
Average DDK Peak Intensity	DDKavi	66.041	dB	71.531	3.290
St. Deviation of DDK Peak Intensity	DDKsdi	0.797	dB	1.397	0.388
Coeff. of Variation of DDK Peak Intensity	DDKcvi	1.206	dB	1.965	0.588
Maximum Intensity of DDK Sample	DDKmxa	68.070	dB	74.418	3.083
Average Intensity of DDK Sample	DDKava	42.415	dB	56.947	2.560
Average Syllabic Intensity	DDKsla	63.750	dB	67.554	2.637

Save As... | Print... | Info... | OK | Cancel

Fig 3.2: *Quantitative output of DDK*

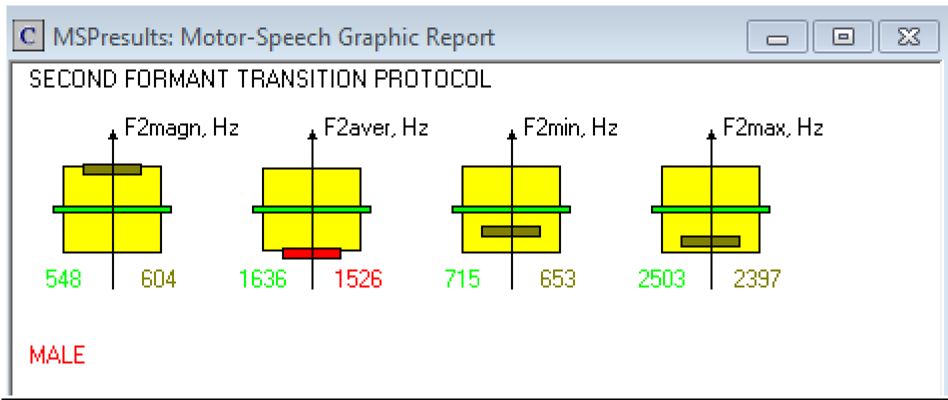


Fig 3.3: *Example of graphical report in MSP*

The module provides a graphical representation of the subject's performance. The yellow area shows + 1 STD. The dark green line shows the value within 1 STD and the red line shows the results which are outside 1 STD.

Statistical analysis

SPSS 17 was used for statistical analysis. Descriptive statistics was done to observe the mean and standard deviation across age and gender. All the data were subjected to the normality test across age and gender. The Shapiro-Wilk test was employed to determine the normality of the data distribution. The result showed that most of the data were not following the normal distribution principle. Hence non-parametric test was used to check the age group and gender comparison. The Kruskal Wallis test was done to see the overall effect of age group. Those parameters which showed a significant difference was further taken up for pair wise comparison. Mann-Whitney U test was carried out to know the gender effect.

CHAPTER 4

RESULTS

The present study aimed to establish normative data for speech motor skills of children aged 4–10 years using Motor Speech Profile (Model 5141) module. The parameters studied were Diadochokinetic rate, second formant transition, voice and tremor parameters, intonation stimulability and Syllabic rate. The study also aimed to find the effect of age and gender on speech motor skills in paediatric population. A total of ninety Kannada speaking typically developing children in the age range of 4-10 years were enrolled as participants for this study. The participants were divided into three subgroups (4-6 years, 6-8 years and 8-10 years), in which each group consisted of 30 members with and equal distribution of male and female. Descriptive statistics was done to observe the mean and standard deviation across age and gender. All the data were subjected to the normality test across age and gender. The Shapiro-Wilk test was employed to determine the normality of the data distribution. The result showed that most of the data were not following the normal distribution principle. Hence non-parametric test was used to check the age group and gender comparison. The Kruskal Wallis test was done to see the overall effect of age group. Those parameters which showed a significant difference was further taken up for pair wise comparison. Mann-Whitney U test was carried out to know the gender effect.

The results of the present study are discussed under five main headings which are further compared across age and gender.

- Diadochokinetic Rate (DDK)
- Second Formant Transition
- Voice and Tremor Parameters
- Intonation Stimulability

- Syllabic Rate

1) **Diadochokinetic Parameters**

There were 4 different tasks in Diadochokinetic rate such as repetition of /pa/, /ta/, /ka/ and /pataka/. The results are discussed according to each task below.

a) **Repetition of /pa/ syllable**

Effect of age group for the task /pa/

Table 4.1 indicates the mean, Standard deviation (SD), Chi square value and p-value for Diadochokinetic rate parameters for the task of /pa/ across age groups. From the table it can be noted that all of the DDK parameters like Average DDK period (DDKavp), Average DDK Rate (DDKavr), Average DDK Peak Intensity (DDKavi), Maximum Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), and Average Syllabic Intensity (DDKsla) has shown a significant age group difference. On observation, it can be inferred that the mean values for the parameters like DDKavr, DDKavi, DDKmxa, DDKava, DDKsla are significantly increasing with an increase in the age. On the other hand, the parameter DDKavp was found to be significantly decreasing with age.

Table 4.1: *Mean, SD, Chi square value and p-value of age group difference for the parameters of DDK task /pa/*

Parameter	**Age group (yrs)**	**Mean (SD)**	***Chi Square value***	***P value***
DDKavp (ms)	4-6	239.05 (24.93)	47.80	0.00**
	6-8	214.64 (27.96)		
	8-10	189.99 (14.22)		
DDKavr (/s)	4-6	4.22 (0.41)	47.80	0.00**
	6-8	4.73 (0.56)		
	8-10	5.29 (0.38		

DDKsdp (ms)	4-6	76.33 (45.19)	2.22	0.33
	6-8	88.22 (49.35)		
	8-10	71.84 (44.09)		
DDKcvp (%)	4-6	31.79 (17.85)	3.59	1.67
	6-8	41.27 (21.25)		
	8-10	38.74 (25.02)		
DDKjit (%)	4-6	7.68 (4.39)	1.69	0.43
	6-8	9.11 (5.44)		
	8-10	7.53 (4.64)		
DDKavi (dB)	4-6	67.17 (9.83)	16.81	0.00**
	6-8	68.75 (7.62)		
	8-10	75.20 (5.15)		
DDKsdi (dB)	4-6	6.25 (2.89)	0.65	0.72
	6-8	5.67(2.46)		
	8-10	5.46 (2.44)		
DDKcvi (%)	4-6	9.29 (4.53)	2.58	0.28
	6-8	8.26 (3.57)		
	8-10	7.31(3.38)		
DDKmxa (dB)	4-6	77.41(11.33)	10.97	0.04*
	6-8	78.54(8.62)		
	8-10	84.79(8.30)		
DDKava (dB)	4-6	52.89(8.06)	27.25	0.00**
	6-8	57.78(7.96)		
	8-10	63.69(4.27)		
DDKsla(dB)	4-6	61.78(7.82)	22.73	0.00**
	6-8	64.18(6.65)		
	8-10	70.36(4.45)		

$P<0.05$, $**p<0.01$

As the mean values for the parameters like DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, DDKsla were found to be showing a significant age group difference, the parameters were subjected to pair wise comparison using Mann-Whitney U test.

Comparison between individual groups for the task /pa/

The table 4.2 shows the pair wise comparison using Mann-Whitney U test between different age groups of all the parameters which showed a significant difference across age group. It can be noted that, when the age groups 4-6y versus 6-8y, were compared, the parameters like DDKavp and DDKavr and DDKava showed a significant difference. Further, in the comparison between the age groups 6-8y versus 8-10y and 4-6y versus 8-10y was carried out; all the parameters such as DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, DDKsla were found to be significantly different.

Table 4.2: *Z- value and p-value of individual age groups for the parameters of the DDK task /pa/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-3.92	0.00**	-4.05	0.00**	-6.36	0.00**
DDKavr (/s)	-3.92	0.00**	-4.05	0.00**	-6.36	0.00**
DDKavi (dB)	-0.74	0.46	-3.71	0.00**	-3.34	0.00**
DDKmxa(dB)	-0.14	0.88	-3.03	0.00**	-2.69	0.01*
DDKava (dB)	-2.32	0.02*	-3.22	0.00**	-5.00	0.00**
DDKsla (dB)	-1.29	0.20	-3.84	0.00**	-4.21	0.00**

**$P<0.05$, **$p<0.01$*

Effect of age group in males for the task /pa/

Kruskal Wallis test was used to compare males across age groups for DDK parameter. It can be noted that all the parameters like DDKavp, DDKavr, DDKavi, DDKava, DDKsla has shown a significant difference across age group. It can be inferred that there is an increase in the mean value of the parameters like DDKavr, DDKavi, DDKmxa, DDKava and DDKsla for males across age group. Also the mean value for the parameter DDKavp was found to be significantly decreasing with age. Table 4.3 represents the Mean, SD, Chi square value and p-value of males across age group for the parameters of DDK task /pa/

Table 4.3: *Mean, SD, Chi square value and p-value of males across age group for the parameters of DDK task /pa/*

Parameter	**Age group(yrs)**	**Mean(D)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	235.57(19.95)	20.85	0.00**
	6-8	220.36(33.50)		
	8-10	192.29(13.80)		
DDKavr (/s)	4-6	4.27(0.34)	20.85	0.00**
	6-8	4.63(0.66)		
	8-10	5.23(0.39)		
DDKsdp (ms)	4-6	90.22(52.40)	3.29	0.19
	6-8	100.14(56.42)		
	8-10	66.45(44.82)		
DDKcvp (%)	4-6	37.92(20.30)	2.21	0.33
	6-8	45.19(22.61)		
	8-10	35.48(25.87)		
DDKjit (%)	4-6	9.31(5.21)	3.26	1.20
	6-8	10.63(6.29)		
	8-10	6.72(4.08)		
DDKavi(dB)	4-6	69.48(10.56)	5.05	0.08
	6-8	68.67(3.77)		
	8-10	73.93(6.02)		
DDKsdi (dB)	4-6	6.44(2.98)	0.02	0.99
	6-8	6.13(2.13)		
	8-10	5.93(2.59)		
DDKcvi (%)	4-6	9.20(4.12)	0.34	0.84
	6-8	8.92(3.14)		
	8-10	8.08(3.66)		
DDKmxa (dB)	4-6	79.63(11.61)	4.54	0.10
	6-8	79.85(6.09)		

	8-10	84.19(5.51)		
DDKava (dB)	4-6	54.20(8.89)	7.88	0.02*
	6-8	57.51(5.47)		
	8-10	62.15(4.70)		
DDKsla(dB)	4-6	63.89(8.21)	6.86	0.03*
	6-8	64.17(3.47)		
	8-10	68.96(4.79)		

**P*<0.05, ***p*<0.01*

The parameters which have shown significance were subjected to pair wise comparison using Mann Whitney U test to find out the individual age group difference.

Comparing between individual age groups for the task /pa/

The table 4.4 shows the results of Mann-Whitney U test between different age groups of those parameters which showed a significant overall age group effect. In the comparison between 4-6y versus 6-8y, it was found that none of the parameters were showing a significant difference. It can be observed that in the further comparisons between the age groups all the parameters were found to be significantly different with an exception of the parameter DDKsla showing a significance in the 4-6y versus 8-10y comparison.

Table 4.4*: Z- value and p-value of individual age groups for the parameters of DDK task /pa/*

	4-6 Vs 6-8 yrs		*6-8 Vs 8-10 yrs*		*4-6 Vs 8-10 yrs*	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-1.93	0.06	-2.34	0.02*	-4.67	0.00**
DDKkavr (/s)	-1.93	0.06	-2.34	0.02*	-4.67	0.00**
DDKava (dB)	-1.10	0.29	-2.26	0.02*	-2.39	0.02*

DDKsla (dB)	-0.31	7.78	-2.76	0.01*	-1.64	0.11

**P<0.05, **p<0.01*

Effect of age group in females for the task /pa/

Female participants were compared across age groups using Kruskal Wallis test. The table 4.5 shows the Mean, Standard deviation (SD), Chi square value and P-value for /pa/ in females across age group. It can be inferred from the table that the parameters such as DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, and DDKsla are showing a significant difference for females across age group. The mean values for the parameters such as DDKavr, DDKsdp, DDKcvp, DDKavi, DDKmxa, DDKava and DDKsla were found to be increasing with age.

Table 4.5: *Mean, SD, Chi square value and p-value of females across age group for the parameters of DDK task /pa/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	242.53(29.39)	27.07	0.00**
	6-8	208.91(20.66)		
	8-10	187.70(14.74)		
DDKavr (/s)	4-6	4.18(0.48)	27.07	0.00**
	6-8	4.83(0.45)		
	8-10	5.35(0.37)		
DDKsdp (ms)	4-6	62.43(32.71)	1.49	0.48
	6-8	76.31(39.48)		
	8-10	77.23(44.23)		
DDKcvp (%)	4-6	25.67(12.93)	5.19	0.08
	6-8	37.34(19.78)		
	8-10	42.00(24.58)		
DDKjit (%)	4-6	6.04(2.64)	1.63	0.44
	6-8	7.60(4.10)		
	8-10	8.35(5.14)		

DDKavi(dB)	4-6	64.86(8.78)	11.90	0.00**
	6-8	68.83(10.30)		
	8-10	76.47(3.93)		
DDKsdi (dB)	4-6	6.07(2.89)	1.21	0.55
	6-8	5.21(2.74)		
	8-10	4.99(2.26)		
DDKcvi (%)	4-6	9.37(5.06)	3.41	0.18
	6-8	7.60(3.95)		
	8-10	6.53(3.00)		
DDKmxa (dB)	4-6	75.18(10.97)	8.75	0.01*
	6-8	77.23(10.64)		
	8-10	85.38(5.38)		
DDKava (dB)	4-6	51.58(7.20)	19.19	0.00**
	6-8	58.04(10.05)		
	8-10	65.24(3.27)		
DDKsla(dB)	4-6	59.67(7.06)	16.90	0.00**
	6-8	64.18(8.92)		
	8-10	71.76(3.73)		

$P<0.05$, $**p<0.01$

Comparing between individual age groups for the task /pa/

Table 4.6 indicates the Z-value and P-value for /pa/ in females for individual age groups were compared. From the table it can be evidently observed that when a higher age group was compared with a lower age group (4-6y versus 8-10y), all the parameters has shown a significant difference. In the comparison between 6-8y versus 8-10y, parameters such as DDKavp, DDKavr, DDKavi, DDKava, DDKsla has shown a significant age group difference. It can be inferred that in all the comparisons, parameters like DDKavp and DDKavr has shown a significant difference across age groups.

Table 4.6*: Z- value and p-value of individual age groups in females for the parameters of DDK task /pa/*

Parameter	***4-6 Vs 6-8 yrs***		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
	Z- value	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-3.55	0.00**	-3.22	0.00**	-4.38	0.00**
DDKavr (/s)	-3.55	0.00**	-3.22	0.00**	-4.38	0.00**
DDKavi (dB)	-1.10	0.28	-2.30	0.02*	-3.34	0.00**
DDKmxa(dB)	-0.85	0.41	-1.93	0.06	-2.93	0.00**
DDKava (dB)	-1.92	0.06	-2.14	0.03*	-4.50	0.00**
DDKsla (dB)	-1.47	0.15	-2.43	0.02*	-4.13	0.00**

$*P<0.05$, $**p<0.01$

Effect of gender for the task /pa/

The table 4.7 represents the Mean, Standard deviation (SD), Chi square value and P-value for /pa/ when males and females were compared. From the table it can be implied that none of the parameters has shown a significant difference indicating that there is no gender wise differences in the parameters of DDK across all the age groups.

Table 4.7*: Mean, SD, Z- value and p-value between gender for the parameters of DDK task /pa/*

Parameter	**Gender**	**Mean (SD)**	***Z- value***	***P- value***
DDKavp (ms)	Male	216.07(29.55)	-0.81	0.42
	Female	213.05(31.64)		
DDKavr (/s)	Male	4.71(0.62)	-0.81	0.42
	Female	4.79(0.65)		
DDKsdp (ms)	Male	85.60(52.25)	-0.99	0.32
	Female	71.99(38.80)		
DDKcvp (%)	Male	39.53(22.89)	-0.95	0.34

	Female	35.00(20.45)		
DDKjit (%)	Male	8.88(5.41)	-1.20	0.23
	Female	7.33(4.12)		
DDKavi (dB)	Male	70.69(7.55)	-1.70	0.87
	Female	70.05(9.32)		
DDKsdi (dB)	Male	6.17(2.54)	-1.26	0.21
	Female	5.42(2.62)		
DDKcvi (%)	Male	8.73(3.61)	-1.31	0.19
	Female	7.84(4.17)		
DDKmxa (dB)	Male	81.22(8.30)	-0.61	0.54
	Female	79.27(10.17)		
DDKava (dB)	Male	57.96(7.25)	-0.44	0.66
	Female	58.28(9.16)		
DDKsla (dB)	Male	65.68(6.17)	-0.04	0.97
	Female	65.20(8.43)		

b) Repetition of /ta/ syllable

Effect of age group for the task /ta/

The table 4.8 shows the mean, Standard Deviation (SD), Chi square value and p-value for Diadochokinetic rate parameters for the task of /ta/ across all age groups. From the table it can be observed that parameters like Average DDK period (DDKavp), Average DDK Rate (DDKavr), Average DDK Peak Intensity (DDKavi), Maximum Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), Average Syllabic Intensity (DDKsla) has shown a significant age group difference. It can be observed that the mean values for the parameters like DDKavr, DDKavi, DDKmxa, DDKava, DDKsla are significantly increasing with an increase in the age. On the other hand, the parameter DDKavp was found to be significantly decreasing with age.

Table 4.8: *Mean, SD, Chi square value and p-value of age group difference for the parameters of DDK task /ta/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	263.14(40.28)	48.76	0.00**
	6-8	216.45(25.65)		
	8-10	193.50(21.21)		
DDKavr (/s)	4-6	3.87(0.51)	48.76	0.00**
	6-8	4.68(0.55)		
	8-10	5.22(0.52)		
DDKsdp (ms)	4-6	61.56(60.30)	1.89	0.39
	6-8	63.53(44.68)		
	8-10	45.75(26.33)		
DDKcvp (%)	4-6	23.52(22.36)	2.82	0.24
	6-8	28.84(18.52)		
	8-10	24.23(14.66)		
DDKjit (%)	4-6	6.58(5.75)	0.34	0.84
	6-8	6.03(4.51)		
	8-10	4.71(2.51)		
DDKavi(dB)	4-6	62.82(9.13)	16.96	0.00**
	6-8	67.20(8.10)		
	8-10	72.95(4.72)		
DDKsdi (dB)	4-6	2.26(1.47)	5.85	0.05
	6-8	3.67(2.57)		
	8-10	2.58(1.63)		
DDKcvi (%)	4-6	3.62(2.25)	5.34	0.07
	6-8	5.51(3.82)		
	8-10	3.54(2.23)		
DDKmxa (dB)	4-6	66.27(9.17)	19.30	0.00**
	6-8	74.12(8.68)		
	8-10	77.51(6.05)		
DDKava (dB)	4-6	52.54(9.23)	23.28	0.00**
	6-8	57.58(8.20)		
	8-10	64.30(4.62)		
DDKsla(dB)	4-6	60.09(8.30)	24.99	0.00**
	6-8	63.43(6.64)		

	8-10	69.92(4.39)	

**P<0.05, **p<0.01*

Further pair wise comparison using Mann Whitney U test was carried out for those parameters which has shown a significant difference across age group.

Comparison between individual age groups for the task /ta/

Table 4.9 shows the pair wise comparison using Mann-Whitney U test between different age groups of all the parameters which showed a significant difference across age group. It can be observed from the comparison between the age groups 4-6y versus 6-8y that, the parameters such as DDKavp, DDKavr and DDKmxa, DDKava are showing a significant difference. When the age groups 6-8y versus 8-10y and 4-6y versus 8-10y were compared most of the parameters showed a significant difference except DDKmxa.

Table 4.9: *Z- value and p-value of individual age groups for the parameters of the DDK task /ta/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-4.86	0.00**	-3.58	0.00**	-6.17	0.00**
DDKavr (/s)	-4.86	0.00**	-3.58	0.00**	-6.17	0.00**
DDKavi (dB)	-1.68	0.09	-2.96	0.00**	-3.74	0.00**
DDKmxa(dB)	-3.13	0.00**	-1.32	0.19	-4.16	0.00**
DDKava (dB)	-2.20	0.03*	-3.22	0.00**	-4.45	0.00**
DDKsla (dB)	-1.33	0.18	-4.27	0.00**	-4.23	0.00**

**P<0.05, **p<0.01*

Effect of age group in males for the task /ta/

It can be noted that all the parameters like DDKavp, DDKavr, DDKava, DDKmxa, DDKsla has shown a significant difference across age group. It can be noted that there is a significant increase in the mean value of the parameters like DDKavr, DDKavi, DDKmxa, DDKava and DDKsla for males across age group. Also the mean value for the parameter DDKavp was found to be significantly decreasing with age. Table 4.10 shows the Mean, Standard Deviation (SD), Chi square value and p-value of males across age groups.

Table 4.10: *Mean, SD, Chi square value and p-value of males across age group for the parameters of DDK task /ta/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	273.59(47.13)	23.10	0.00**
	6-8	218.31(28.92)		
	8-10	196.37(21.99)		
DDKavr (/s)	4-6	3.75(0.59)	23.10	0.00**
	6-8	4.65(0.59)		
	8-10	5.15(0.55)		
DDKsdp (ms)	4-6	70.55(70.82)	3.42	0.18
	6-8	69.58(50.60)		
	8-10	39.93(26.31)		
DDKcvp (%)	4-6	25.73(25.14)	2.58	0.28
	6-8	31.07(19.65)		
	8-10	20.94(14.77)		
DDKjit (%)	4-6	6.94(6.00)	2.53	0.28
	6-8	6.59(4.94)		
	8-10	3.90(1.97)		
DDKavi(dB)	4-6	62.70(10.13)	9.97	0.00**
	6-8	65.97(6.35)		
	8-10	72.71(6.35)		
DDKsdi (dB)	4-6	2.15(1.63)	2.42	0.30

	6-8	3.35(2.71)		
	8-10	2.24(1.48)		
DDKcvi (%)	4-6	3.45(2.49)	3.35	0.19
	6-8	5.02(3.89)		
	8-10	3.04(1.91)		
DDKmxa (dB)	4-6	66.16(10.59)	7.07	0.03*
	6-8	71.90(7.82)		
	8-10	77.17(8.43)		
DDKava (dB)	4-6	52.37(9.41)	13.12	0.00**
	6-8	56.62(6.48)		
	8-10	63.62(6.19)		
DDKsla(dB)	4-6	60.01(8.82)	12.25	0.00**
	6-8	62.41(4.71)		
	8-10	69.19(5.76)		

**P<0.05, **p<0.01*

The parameters which have shown significance were subjected to pair wise comparison using Mann Whitney U test to find out the individual age group difference.

Comparison between all age groups for the task /ta/

The table 4.11 shows the pair wise comparison between different age groups of those parameters which showed a significant overall age group effect. In the comparison between 4-6 and 6-8, it was found that parameters like DDKavp and DDKavr has shown a significant difference. It can be observed that when the age group 4-6y was compared with 8-10y most of the parameters has shown a significant difference when compared to the comparisons between younger age groups.

Table 4.11*: Z- value and p-value of individual age groups for the parameters of DDK task /ta/*

Parameter	***4-6 Vs 6-8 yrs***		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
	Z- value	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-3.38	0.00**	-2.01	0.05	-4.38	0.00**
DDKavr (/s)	-3.38	0.00**	-2.01	0.05	-4.38	0.00**
DDKavi (dB)	-1.14	0.27	-2.97	0.00**	-2.39	0.02*
DDKmxa(dB)	-1.76	0.08	-1.56	0.13	-2.30	0.02*
DDKava (dB)	-1.64	0.11	-2.80	0.00**	-3.09	0.00**
DDKsla (dB)	-1.18	0.25	-3.21	0.00**	-2.72	0.01*

**P<0.05, **p<0.01*

Effect of age group in females for the task /ta/

Female participants were compared across age groups using Kruskal Wallis test. The table above shows the Mean, Standard Deviation (SD), Chi square value and P-value for /ta/ in females across age group. It can be observed from the table that the parameters like DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, and DDKsla are showing a significant difference for males across age group. The mean values for the parameters such as DDKavr, DDKsdp, DDKcvp, DDKavi, DDKmxa, DDKava and DDKsla were found to be increasing with age indicating a developmental trend.

Table 4.12: *Mean, SD, Chi square value and p-value of females across age group for the parameters of DDK task /ta/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	252.69(30.08)	25.40	0.00**
	6-8	214.59(22.79)		
	8-10	19.063(20.75)		
DDKavr (/s)	4-6	4.00(0.39)	25.40	0.00**

	6-8	4.71(0.51)		
	8-10	5.30(0.50)		
DDKsdp (ms)	4-6	52.58(48.41)	1.02	0.60
	6-8	57.48(38.68)		
	8-10	51.57(25.90)		
DDKcvp (%)	4-6	21.32(19.83)	2.79	0.25
	6-8	26.60(17.71)		
	8-10	27.52(14.29)		
DDKjit (%)	4-6	6.22(5.67)	0.27	0.87
	6-8	5.47(4.14)		
	8-10	5.52(2.79)		
DDKavi(dB)	4-6	62.95(8.35)	8.87	0.01*
	6-8	68.42(9.61)		
	8-10	73.19(2.38)		
DDKsdi (dB)	4-6	2.36(1.33)	4.22	0.12
	6-8	3.99(2.46)		
	8-10	2.92(1.74)		
DDKcvi (%)	4-6	3.79(2.06)	2.96	0.23
	6-8	6.00(3.82)		
	8-10	4.03(2.48)		
DDKmxa (dB)	4-6	66.39(7.88)	16.39	0.00**
	6-8	76.34(9.19)		
	8-10	77.85(2.08)		
DDKava (dB)	4-6	52.70(9.37)	9.89	0.01*
	6-8	58.54(9.76)		
	8-10	64.88(4.62)		
DDKsla(dB)	4-6	60.17(8.04)	14.14	0.00**
	6-8	64.46(8.17)		
	8-10	70.66(2.35)		

$P<0.05$, $p<0.01$

**P<0.05, **p<0.01*

Those parameters which has shown a significant difference was further subjected to Mann Whitney U test to find out the between age effect.

Comparison between individual age groups for the task /ta/

Table 4.13 shows the Z-value and P-value for /pa/ in females when individual age groups were compared. From the table it can be noted that when a higher age group was compared with a lower age group (4-6y versus 8-10y), all the parameters has shown a significant difference in the comparison with 6-8y versus 8-10y, parameters like DDKavp, DDKavr and DDKsla has shown a significant age group difference.

Table 4.13*: Z- value and p-value of individual age groups in females for the parameters of DDK task /ta/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-3.55	0.00**	-2.76	0.01*	-4.34	0.00**
DDKavr (/s)	-3.55	0.00**	-2.76	0.01*	-4.34	0.00**
DDKavi (dB)	-1.85	0.07	-0.73	0.49	-3.05	0.00**
DDKmxa(dB)	-2.97	0.00**	-0.27	0.81	-4.00	0.00**
DDKava (dB)	-1.68	0.10	-1.43	0.16	-3.13	0.00**
DDKsla (dB)	-1.35	0.19	-2.76	0.01*	-3.42	0.00**

**P<0.05, **p<0.01*

Effect of gender

Table 4.14 shows the Mean, Standard Deviation (SD), Chi square value and P-value for /ta/ when males and females were compared. From the table it can be noted that none of the parameters of DDK has shown a significant difference indicating that there is no gender wise differences within the age group of 4-10 years.

Table 4.14*: Mean, SD, Z- value and p-value between gender for the parameters of DDK task /ta/*

Parameter	**Gender**	**Mean (SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	Male	229.42(46.97)	-0.75	0.46
	Female	219.30(35.47)		
DDKavr (/s)	Male	4.52(0.81)	-0.75	0.46
	Female	4.67(0.71)		
DDKsdp (ms)	Male	60.02(53.27)	-0.16	0.88
	Female	53.88(37.98)		
DDKcvp (%)	Male	25.91(20.27)	-0.11	0.91
	Female	25.14(17.25)		
DDKjit (%)	Male	5.81(4.72)	-0.01	0.99
	Female	5.73(4.27)		
DDKavi(dB)	Male	67.12(8.73)	-0.42	0.68
	Female	68.19(8.45)		
DDKsdi (dB)	Male	2.58(2.05)	-1.82	0.07
	Female	3.09(1.98)		
DDKcvi (%)	Male	3.84(2.95)	-1.70	0.09
	Female	4.61(2.99)		
DDKmxa (dB)	Male	71.74(9.92)	-1.04	0.30
	Female	73.52(8.63)		
DDKava (dB)	Male	57.54(8.70)	-0.81	0.42
	Female	58.71(9.23)		
DDKsla (dB)	Male	63.87(7.60)	-0.80	0.42
	Female	65.10(7.91)		

c) Repetition of /ka/ syllable

Effect of age group for the task /ka/

Table 4.15 shows the mean, Standard Deviation (SD), Chi square value and p-value for Diadochokinetic rate parameters for the task of /ta/ across all age groups. From the table it can be observed that most of the DDK parameters like Average DDK period (DDKavp), Average DDK Rate (DDKavr), Pertubation of DDK Period

(DDKjit), Average DDK Peak Intensity (DDKavi),) Coefficient of Variation of DDK Peak Intensity (DDKcvi),Maximum Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), Average Syllabic Intensity (DDKsla) has shown a significant age group difference.0n observation, it can be inferred that the mean values for the parameters like DDKavr, DDKavi, DDKmxa, DDKava, DDKsla are significantly increasing with an increase in the age. On the other hand, the parameter DDKavp was found to be significantly decreasing with age.

Table 4.15: *Mean, SD, Chi square value and p-value of age group difference for the parameters of DDK task /ka/.*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	262.66(44.92)	46.46	0.00**
	6-8	210.24(20.39)		
	8-10	198.41(18.48)		
DDKavr (/s)	4-6	3.90(0.58)	46.46	0.00**
	6-8	4.80(0.46)		
	8-10	5.08 (0.74)		
DDKsdp (ms)	4-6	73.75(48.76)	6.98	0.03*
	6-8	61.73(44.54)		
	8-10	43.47 (28.76)		
DDKcvp (%)	4-6	27.25(15.58)	2.22	0.33
	6-8	29.21(20.90)		
	8-10	21.74 (14.05)		
DDKjit (%)	4-6	7.53(5.45)	6.47	0.04*
	6-8	5.68(4.23)		
	8-10	4.37 (2.94)		
DDKavi(dB)	4-6	61.34(9.59)	25.96	0.00**
	6-8	65.96(8.40)		
	8-10	73.36 (4.24)		
DDKsdi (dB)	4-6	3.15(1.75)	4.62	0.10
	6-8	3.07(2.26)		
	8-10	2.44 (1.72)		

DDKcvi (%)	4-6	5.14(2.67)	9.37	0.01*
	6-8	4.59(3.15)		
	8-10	3.32 (2.26)		
DDKmxa (dB)	4-6	65.99(9.86)	19.25	0.00**
	6-8	70.17(8.91)		
	8-10	77.46 (4.99)		
DDKava (dB)	4-6	50.14(9.53)	36.00	0.00**
	6-8	55.27(8.16)		
	8-10	63.33 (4.79)		
DDKsla(dB)	4-6	59.00(8.53)	33.94	0.00**
	6-8	62.07(6.15)		
	8-10	69.60 (3.82)		

$^*P<0.05$, $^{**}p<0.01$

As the mean values for the parameters like DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, DDKsla were found to be showing a significant age group difference, the parameters were subjected to pair wise comparison using Mann-Whitney U test to find out the individual age group difference.

Comparison between individual age groups for the task /ka/

Table 4.16 represents the pair wise comparison using Mann-Whitney U test between different age groups of all the parameters which showed a significant difference across age group. It can be observed that, when the age groups 4-6y versus 6-8y, were compared, the parameters such as DDKava and DDKavr showed a significant difference. Further, in the comparison between the age groups 6-8y versus 8-10y parameters like DDKavp and DDKavr, DDKavi, DDKmxa, DDKava and DDKsla showed significance. Finally, it was noted that all the parameters were showing a significant age group difference when the age groups 4-6y and 8-10y were compared.

Table 4.16: *Z- value and p-value of individual age groups for the parameters of the DDK task /ka/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z -value***	***P- value***	***Z -value***	***P- value***
DDKavp (ms)	-5.35	0.00**	-2.20	0.03*	-6.05	0.00**
DDKavr (/s)	-5.35	0.00**	-2.20	0.03*	-6.05	0.00**
DDKjit (%)	-1.52	0.13	-0.95	0.34	-2.54	0.01*
DDKavi (dB)	-1.88	0.06	-4.05	0.00**	-4.42	0.00**
DDKcvi (%)	-1.57	0.12	-1.41	0.16	-3.09	0.00**
DDKmxa(dB)	-1.36	0.17	-3.49	0.00**	-3.87	0.00**
DDKava (dB)	-2.29	0.02*	-4.51	0.00**	-5.37	0.00**
DDKsla (dB)	-1.26	0.21	-5.50	0.00**	-4.52	0.00**

**P<0.05, **p<0.01*

Effect of age group in males for the task /ka/

Table 4.17 shows the mean, Standard deviation, Chi Square value and P-value of males across age groups for DDK parameter. It can be noted that all the parameters like DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, DDKsla has shown a significant difference across age group for males. It can be observed that there is an increase in the mean value of the parameters like DDKavr, DDKavi, DDKmxa, DDKava and DDKsla for males across age. Also the mean value for the parameter DDKavp was found to be significantly decreasing with age.

Table 4.17: *Mean, SD, Chi square value and p-value of males across age group for the parameters of DDK task /ka/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value (λ)***	***P- value***
DDKavp (ms)	4-6	256.68(37.45)	24.45	0.00**

	6-8	206.38(22.35)		
	8-10	196.37 (13.44)		
DDKavr (/s)	4-6	3.97(0.52)	24.45	0.00**
	6-8	4.90(0.50)		
	8-10	5.11 (0.34)		
DDKsdp (ms)	4-6	55.62(32.48)	5.08	0.08
	6-8	43.53(36.93)		
	8-10	32.32 (22.04)		
DDKcvp (%)	4-6	21.55(12.48)	1.46	0.48
	6-8	21.20(18.11)		
	8-10	16.32 (10.76)		
DDKjit (%)	4-6	5.37(3.12)	4.92	0.09
	6-8	4.05(3.07)		
	8-10	3.22 (2.13)		
DDKavi(dB)	4-6	61.39(10.27)	8.13	0.02*
	6-8	65.21(7.08)		
	8-10	72.05 (5.57)		
DDKsdi (dB)	4-6	2.70(1.34)	3.17	0.21
	6-8	3.06(2.44)		
	8-10	1.98 (1.06)		
DDKcvi (%)	4-6	4.42(2.01)	5.72	0.06
	6-8	4.58(3.42)		
	8-10	2.76 (1.49)		
DDKmxa (dB)	4-6	65.65(9.87)	6.73	0.04*
	6-8	70.10(8.69)		
	8-10	76.04 (5.97)		
DDKava (dB)	4-6	49.90(9.75)	14.41	0.00**
	6-8	54.37(6.71)		
	8-10	62.01 (6.46)		
DDKsla(dB)	4-6	59.30(9.04)	11.78	0.00**
	6-8	61.66(4.57)		
	8-10	68.39 (5.00)		

$P<0.05$, $**p<0.01$

The parameters which have shown significance were subjected to pair wise comparison using Mann Whitney U test to find out the individual age group difference.

Comparison between individual age groups for the task /ka/

Table 4.18 represents the pair wise comparison between different age groups of those parameters which showed a significant overall age group effect. In the comparison between 4-6y versus 6-8y, it was found that parameters like DDKavp and DDKavr has shown a significant difference. When the age groups 6-8y and 8-10y were compared, parameters like DDKavi, DDKava and DDKsla showed a significant difference. It can be observed that in the further comparisons between the age groups 4-6 versus 8-10, all the parameters has shown a significant difference.

Table 4.18*: Z- value and p-value of individual age groups for the parameters of DDK task /ka/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P -value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp (ms)	-3.88	0.00**	-1.22	0.23	-4.46	0.00**
DDKavr (/s)	-3.88	0.00**	-1.22	0.23	-4.46	0.00**
DDKavi (dB)	-1.27	0.21	-2.63	0.01*	-2.14	0.03*
DDKmxa(dB)	-1.06	0.30	-1.80	0.07	-2.39	0.02*
DDKava (dB)	-1.68	0.10	-2.80	0.00**	-3.34	0.00**
DDKsla (dB)	-1.14	0.27	-3.63	0.00**	-2.26	0.02*

**P<0.05, **p<0.01*

Effect of age group in females for the task /ka/

Females were compared across age groups using Kruskal Wallis test. The table above shows the Mean, Standard Deviation (SD), Chi square value and P-value for /pa/ in females across age group. It can be inferred from the table that the parameters such as DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, and DDKsla are showing a significant difference for females across age group. The mean values for the parameters such as DDKavr, DDKsdp, DDKavi, DDKmxa, DDKava and DDKsla were found to be significantly increasing with age.

Table 4.19: *Mean, SD, Chi square value and p-value of females across age group for the parameters of DDK task /ka/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	268.64(51.96)	21.77	0.00**
	6-8	214.10(18.15)		
	8-10	200.45 (22.76)		
DDKavr (/s)	4-6	3.84(0.64)	21.77	0.00**
	6-8	4.70(0.41)		
	8-10	5.05 (0.58)		
DDKsdp (ms)	4-6	91.87(56.27)	3.91	0.14
	6-8	79.93(45.12)		
	8-10	54.62 (31.00)		
DDKcvp (%)	4-6	32.94(16.66)	1.56	0.46
	6-8	37.23(20.95)		
	8-10	27.16 (15.18)		
DDKjit (%)	4-6	9.69(6.47)	3.72	0.16
	6-8	7.32(4.67)		
	8-10	5.52(3.25)		
DDKavi(dB)	4-6	61.29(9.22)	19.17	0.00**
	6-8	66.71(9.75)		
	8-10	74.66(1.63)		
DDKsdi (dB)	4-6	3.60(2.02)	2.42	0.30
	6-8	3.07(2.14)		
	8-10	2.91(2.13)		
DDKcvi (%)	4-6	5.85(3.10)	4.39	0.11
	6-8	4.61(2.98)		
	8-10	3.88 (2.76)		

DDKmxa (dB)	4-6	66.34(10.18)	15.35	0.00**
	6-8	70.25(9.44)		
	8-10	78.88(3.40)		
DDKava (dB)	4-6	50.39(9.64)	23.01	0.00**
	6-8	56.17(9.56)		
	8-10	64.65(1.45)		
DDKsla(dB)	4-6	58.70(8.29)	24.69	0.00**
	6-8	62.48(7.56)		
	8-10	70.80 (1.47)		

**P<0.05, **p<0.01*

The parameters which have shown significance were subjected to pair wise comparison using Mann Whitney U test to find out the individual age group difference.

Comparison between individual groups

Table 4.20 represents the pair wise comparison using Mann-Whitney U test between different age groups of those parameters which showed a significant overall age group effect. In the comparison between 4-6y versus 6-8y, it was found that parameters like DDKavp and DDKavr has shown a significant difference. It can be observed that in the further comparisons between the age groups all the parameters were found to be significantly different with an exception of the parameter DDKavp and DDKavr not showing significance in the 6-8y versus and 8-10y comparison.

Table 4.20*: Z- value and p-value of individual age groups for the parameters of DDK task /ka/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp(ms)	-3.63	0.00**	-1.72	0.09	-4.09	0.00**
DDKavr (/s)	-3.63	0.00**	-1.72	0.09	-4.09	0.00**
DDKavi (dB)	-1.47	0.14	-3.05	0.00**	-4.13	0.00**
DDKmxa(dB)	-0.89	0.39	-3.38	0.00**	-3.30	0.00**

DDKava (dB)	-1.76	0.08	-3.42	0.00**	-4.42	0.00**
DDKsla (dB)	-0.77	0.46	-4.17	0.00**	-4.34	0.00**

**P<0.05, **p<0.01*

Effect of gender for the task /ka/

The table 4.21 shows the Mean, Standard Deviation (SD), Chi square value and P-value for /pa/ when males and females were compared. It can be observed that the parameters like DDKsdp, DDKcvp and DDKjit has shown a significant gender wise difference across age group.

Table 4.21*: Mean, SD, Z- value and p-value between gender for the parameters of DDK task /ka/*

Parameter	**Gender**	**Mean (SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	Male	219.81 (37.08)	-0.99	0.32
	Female	227.73 (44.90)		
DDKavr (/s)	Male	4.66 (0.68)	-0.99	0.32
	Female	4.53 (0.75)		
DDKsdp (ms)	Male	43.82 (31.89)	-3.58	0.00**
	Female	75.47 (46.99)		
DDKcvp (%)	Male	19.69 (14.02)	-3.72	0.00**
	Female	32.44(17.85)		
DDKjit (%)	Male	4.21 (2.89)	-3.63	0.00**
	Female	7.51(5.16)		
DDKavi(dB)	Male	66.22 (8.90)	-0.67	0.50
	Female	67.55(9.43)		
DDKsdi (dB)	Male	2.58 (1.74)	-1.30	0.19
	Female	3.19 (2.07)		
DDKcvi (%)	Male	3.92(2.53)	-1.31	0.17
	Female	4.78(3.00)		
DDKmxa (dB)	Male	70.60(9.22)	-0.79	0.43

	Female	71.82(9.65)		
DDKava (dB)	Male	55.42(9.13)	-1.03	0.30
	Female	57.07(9.71)		
DDKsla (dB)	Male	63.12(7.47)	-0.67	0.50
	Female	63.99(8.18)		

**P<0.05, **p<0.01*

Comparison between /pa/, /ta/ and /ka/

The mean values of /pa/, /ta/ and /ka/ were subjected to statistical analysis using Kruskal Wallis test in order to compare the values for the 3 tasks. Results revealed few parameters showed significant difference between the tasks and few are not. Since majority of the parameters showed a significant difference, the normative data (Table 4.56) was retained separately for /pa/, /ta/ and /ka/. Table 4.22 represents the comparison of mean values of /pa/, /ta/ and /ka/.

Table 4.22: *Chi square value and p value showing the comparison between /pa/, /ta/ and /ka/.*

Parameter	***Chi Square value***	***P value***
DDKavp (ms)	2.48	0.29
DDKavr (/s)	2.47	0.29
DDKsdp (ms)	16. 13	0.00**
DDKcvp (%)	19.30	0.00**
DDKjit (%)	19.50	0.00**
DDKavi(dB)	4.42	0.11
DDKsdi (dB)	68.92	0.00**
DDKcvi (%)	64.70	0.00**
DDKmxa (dB)	40.40	0.00**
DDKava (dB)	3.87	0.15

DDKsla(dB)	2.24	0.33

d) Repetition of /pataka/

Effect of age group for the task /pataka/

Table 4.23 represents the mean, Standard Deviation (SD), Chi square value *and p-value for Diadochokinetic* rate parameters for the task of /pataka/ across all age groups. The above results indicate that parameters like Average DDK period (DDKavp), Average DDK Rate (DDKavr), Average DDK Peak Intensity (DDKavi), Maximum Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), Average Syllabic Intensity(DDKsla) has shown a significant age group difference. It can be understood that the mean values for the parameters like DDKavr, DDKavi, DDKmxa, DDKava, DDKsla are significantly increasing with an increase in the age. On the other hand, the parameter DDKavp was found to be significantly decreasing with age.

Table 4.23: *Mean, SD, Chi square value and p-value of age group difference for the parameters of DDK task /pataka*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	242.07(40.59)	38.63	0.00**
	6-8	197.44(26.35)		
	8-10	184.81(14.54)		
DDKavr (/s)	4-6	4.22(0.68)	39.78	0.00**
	6-8	5.15(0.65)		
	8-10	5.44(0.44)		
DDKsdp (ms)	4-6	103.48(55.48)	1.30	0.52
	6-8	105.22(67.62)		
	8-10	85.52(24.66)		
DDKcvp (%)	4-6	41.93(20.36)	2.39	0.30
	6-8	51.41(25.64)		

	8-10	46.19(12.67)		
DDKjit (%)	4-6	11.08(5.87)	1.51	0.47
	6-8	11.48(5.49)		
	8-10	9.58(3.45)		
DDKavi(dB)	4-6	63.29(9.01)	9.89	0.01*
	6-8	65.83(6.65)		
	8-10	69.75(5.15)		
DDKsdi (dB)	4-6	7.03(3.72)	1.22	0.54
	6-8	7.48(3.28)		
	8-10	7.84(2.86)		
DDKcvi (%)	4-6	11.01(5.39)	0.12	0.94
	6-8	11.46(5.05)		
	8-10	11.26(3.99)		
DDKmxa (dB)	4-6	76.59(10.88)	8.64	0.01*
	6-8	79.83(7.98)		
	8-10	84.06(6.15)		
DDKava (dB)	4-6	48.88(7.90)	16.90	0.00**
	6-8	53.45(7.61)		
	8-10	57.61(4.94)		
DDKsla(dB)	4-6	58.74(8.54)	9.57	0.01*
	6-8	61.56(5.44)		
	8-10	64.54(5.27)		

**P<0.05, **p<0.01*

Further pair wise comparison using Mann Whitney U test was carried out for those parameters which has shown a significant difference across age group.

Comparison between individual age groups for the task /pataka/

Table 4.24 shows the Z- value and p-value for different age groups of all the parameters which showed a significant difference across age group. It can be implied from the comparison between the age groups 4-6y and 6-8y that, the parameters such as DDKavp, DDKavr and DDKava were showing a significant difference. When the age groups 6-8y versus 8-10y and 4-6y and 8-10y were compared all the parameters except the parameter DDKava in the 6-8y versus 8-10y comparison has shown a significant difference.

Table 4.24: *Z- value and p-value of individual age groups for the parameters of the DDK task /pataka/*

Parameter	***4-6 Vs 6-8 yrs***		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
	Z- value	***P- value***	***Z- value***	***P- value***	***Z- value***	***P -value***
DDKavp (ms)	-4.33	0.00**	-2.17	0.03*	-5.86	0.00**
DDKavr (/s)	-4.50	0.00**	-2.17	0.03*	-5.89	0.00**
DDKavi(dB)	-1.32	0.19	-2.38	0.02*	-2.77	0.01*
DDKmxa(dB)	-0.88	0.38	-2.16	0.03*	-2.74	0.01*
DDKava (dB)	-2.37	0.01*	-1.96	0.05	-3.98	0.00**
DDKsla (dB)	-1.57	0.12	-2.03	0.04*	-2.81	0.01*

**$P<0.05$, **$p<0.01$*

Effect of age group in males for the task /pataka/

Table 4.25 the Mean, Standard Deviation (SD), Chi square value and p-value of males across age groups. It can be noted that all the parameters like DDKavp, DDKavr, DDKava, DDKmxa, DDKsla has shown a significant difference across age group. It can be inferred that there is a significant increase in the mean value of the parameters like DDKavr, DDKavi, DDKmxa, DDKava and DDKsla for males across age group. Also the mean value for the parameter DDKavp was found to be significantly decreasing with age.

Table 4.25: *Mean, SD, Chi square value and p-value of males across age group for the parameters of DDK task /pataka*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	233.39(36.27)	17.87	0.00**
	6-8	197.51(30.00)		
	8-10	186.54(10.37)		
DDKavr (/s)	4-6	4.34(0.64)	18.56	0.00**
	6-8	5.16(0.67)		
	8-10	5.38(0.30)		
DDKsdp (ms)	4-6	110.46(62.28)	2.40	0.30
	6-8	126.05(82.61)		
	8-10	85.29(28.92)		
DDKcvp (%)	4-6	46.56(23.67)	3.09	0.21
	6-8	61.13(28.33)		
	8-10	45.52(14.85)		
DDKjit (%)	4-6	11.53(6.32)	1.17	0.56
	6-8	13.07(5.56)		
	8-10	10.38(3.95)		
DDKavi(dB)	4-6	63.17(10.39)	3.90	0.14
	6-8	64.76(5.50)		
	8-10	68.10(5.43)		
DDKsdi (dB)	4-6	6.37(3.30)	2.94	0.23
	6-8	7.92(3.47)		
	8-10	7.73(2.91)		
DDKcvi (%)	4-6	10.05(4.82)	1.87	0.39
	6-8	12.36(5.52)		
	8-10	11.30(3.94)		
DDKmxa (dB)	4-6	75.42(11.47)	3.90	0.14
	6-8	80.23(6.87)		
	8-10	82.61(7.74)		
DDKava (dB)	4-6	49.17(9.24)	5.67	0.06
	6-8	52.73(6.64)		
	8-10	56.41(5.50)		
DDKsla(dB)	4-6	59.38(9.76)	2.60	0.27
	6-8	61.33(4.09)		

	8-10	63.05(5.63)	

*P<0.05, **p<0.01

The parameters which have shown significance were subjected to pair wise comparison using Mann Whitney U test to find out the individual age group difference.

Comparison between individual groups for the task /pataka/

Table 4.26 shows the Z-value and P-value for /pataka/ when individual age groups were compared. From the table it can be noted that when a higher age group was compared with a lower age group (4-6y versus 8-10y), all the parameters has shown a significant difference. There were no significant differences seen when the age groups 6-8y versus 8-10y were compared.

Table 4.26*: Z- value and p-value of individual age groups for the parameters of DDK task /pataka/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z -value***	***P -value***	***Z -value***	***P -value***	***Z -value***	***P- value***
DDKavp (ms)	-2.88	0.00**	-0.93	0.37	-4.67	0.00**
DDKavr (/s)	-3.05	0.00**	-0.93	0.37	-4.17	0.00**

*P<0.05, **p<0.01

Effect of age group in females for the task /pataka/

Kruskal Wallis test was used for the comparison across age groups in females. The table above shows the Mean, Standard Deviation (SD), Chi square value and P-value for /pataka/ in females across age group. It can be observed from the table that the parameters like DDKavp, DDKavr, DDKavi, DDKmxa, DDKava, and DDKsla are showing a significant difference for females across age group. The mean values for the parameters such as DDKavr, DDKsdp, DDKcvp, DDKavi, DDKmxa, DDKava and DDKsla were found to be increasing with age.

Table 4.27: *Mean, SD, Chi square value and p-value of females across age group for the parameters of DDK task /pataka/*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	4-6	250.74(44.00)	21.81	0.00**
	6-8	197.36(23.20)		
	8-10	183.08(18.00)		
DDKavr (/s)	4-6	4.10(0.72)	21.81	0.00**
	6-8	5.14(0.66)		
	8-10	5.51(0.55)		
DDKsdp (ms)	4-6	96.50(48.92)	0.31	0.86
	6-8	84.39(41.44)		
	8-10	85.75(20.57)		
DDKcvp (%)	4-6	37.30(15.91)	3.25	0.20
	6-8	41.70(18.88)		
	8-10	46.87(10.54)		
DDKjit (%)	4-6	10.64(5.58)	0.82	0.67
	6-8	9.89(5.10)		
	8-10	8.77(2.77)		
DDKavi(dB)	4-6	63.41(7.76)	7.52	0.02*
	6-8	66.90(7.67)		
	8-10	71.40(4.43)		
DDKsdi (dB)	4-6	7.69(4.10)	0.40	0.82
	6-8	7.05(3.14)		
	8-10	7.94(2.91)		
DDKcvi (%)	4-6	11.98(5.91)	0.63	0.73
	6-8	10.57(4.55)		
	8-10	11.21(4.19)		
DDKmxa (dB)	4-6	77.76(10.52)	5.08	0.08
	6-8	79.43(9.18)		
	8-10	85.50(3.74)		
DDKava (dB)	4-6	48.59(6.61)	11.85	0.00**

	6-8	54.17(8.82)		
	8-10	58.81(4.15)		
DDKsla(dB)	4-6	58.09(7.42)	8.35	0.02*
	6-8	61.78(6.66)		
	8-10	66.02(4.60)		

$P<0.05$, $**p<0.01$

Comparison between individual age groups for the task /pataka/

Table 4.28 shows the Z- value and P-value for /pataka/ in females when individual age groups were compared. From the table it can be noted that when a higher age group was compared with a lower age group (4-6y versus 8-10y), all the parameters has shown a significant difference. In the comparison between 6-8y versus 8-10y, parameters like DDKavp, DDKavr and DDKsla has shown a significant age group difference.

Table 4.28*: Z- value and p-value of individual age groups in females for the parameters of DDK task /pataka/*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
DDKavp(ms)	-3.42	0.00**	-2.05	0.04*	-4.13	0.00**
DDKavr (/s)	-3.42	0.00**	-2.05	0.04*	-4.13	0.00**
DDKavi(dB)	-1.31	0.20	-1.51	0.14	-2.68	0.01*
DDKava(dB)	-1.76	0.08	-1.20	0.23	-3.63	0.00**
DDKsla (dB)	-1.18	0.24	-1.64	0.11	-2.88	0.00**

$P<0.05$, $**p<0.01$

Effect of gender for the task /pataka/

Table 4.29 shows the Mean, Standard Deviation (SD), Chi square value and P-value for /pa/ when males and females were compared. From the table it can be noted that none of the parameters of DDK has shown a significant difference indicating that there is no gender wise differences within the age group of 4-10 years.

Table 4.29: Mean, SD, Z- value and p-value between gender for the parameters of DDK task /pataka/

Parameter	**Gender**	**Mean (SD)**	***Chi Square value***	***P- value***
DDKavp (ms)	Male	205.82(33.89)	-0.42	0.67
	Female	210.39(41.93)		
DDKavr (/s)	Male	4.96(0.71)	-0.33	0.74
	Female	4.92(0.87)		
DDKsdp (ms)	Male	107.26(62.93)	-1.14	0.25
	Female	88.88(38.37)		
DDKcvp (%)	Male	51.07(23.57)	-1.70	0.09
	Female	41.96(15.65)		
DDKjit (%)	Male	11.66(5.36)	-1.72	0.09
	Female	9.77(4.61)		
DDKavi(dB)	Male	65.34(7.60)	-1.38	0.17
	Female	67.24(7.42)		
DDKsdi (dB)	Male	7.34(3.24)	-0.27	0.79
	Female	7.56(3.37)		
DDKcvi (%)	Male	11.24(4.79)	-0.01	0.99
	Female	11.25(4.86)		
DDKmxa (dB)	Male	79.42(9.22)	-0.59	0.56
	Female	80.90(8.82)		
DDKava (dB)	Male	52.77(7.67)	-0.50	0.61
	Female	53.86(7.87)		
DDKsla (dB)	Male	61.25(6.93)	-0.74	0.46
	Female	61.97(7.01)		

2) Second formant transition (F2 transition)

Effect of age group on F2 transition

Table 4.30 indicates the mean, Standard Deviation (SD), Chi square value and p-value for the parameters of F2 transition across all age groups. The results showed that the majority of the parameters have a significant age group difference except F2 regularity and F2 maximum parameter. The mean value and SD for parameter F2 magnitude was found to be decreasing with an increase in age. The parameter F2 rate (no. of syllables per sec) was found to be significantly increasing with age.

Table 4.30: *Mean, SD, Chi square value and p-value of age group difference for F2 transition*

Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value (λ)***	***P- value***
F2magn (Hz)	4-6	509 (159.18)	13.98	0.00**
	6-8	405 (132.8)		
	8-10	375 (109.1)		
F2rate (/s)	4-6	1.71(1.10)	6.98	0.03*
	6-8	1.81(1.18)		
	8-10	1.90(0.60)		
F2reg (%)	4-6	58.97(12.56)	0.48	0.80
	6-8	62.00(13.67)		
	8-10	61.45(13.58)		
F2aver (Hz)	4-6	4622 (216.9)	6.73	0.04*
	6-8	4763 (249.2)		
	8-10	4611 (247.8)		
F2min (Hz)	4-6	2684 (601.56)	11.76	0.00**
	6-8	3212 (601.5)		
	8-10	3145.3 (614.1)		
F2max (Hz)	4-6	5977 (517.80)	3.91	0.14
	6-8	6149 (844)		

8-10	6440 (902)	

**P<0.05, **p<0.01*

The parameters like F2 magnitude (Hz), F2 rate (/s), F2 average (Hz), F2 minimum (Hz) were found to be showing a significant age group difference. The parameters were subjected to pair wise comparison using Mann- Whitney U test.

Comparison between all the age groups for F2 transition

Table 4.31 shows the pair wise comparison using Mann-Whitney U test between different age groups of those parameters which showed a significant difference across age group. In the comparison between the age groups 4-6y versus 6-8y, the parameter F2aver, F2magn and F2min showed a significant difference .When the age groups 6-8y versus 8-10y were compared only F2aver showed a significant difference. There was a significant difference for the parameters such as F2rate, and F2min and F2mag, when the age groups of 4-6 versus 8-10 years were subjected to pair wise comparison.

Table 4.31: *Z- value and p-value of individual age groups for F2 transition*

	4-6 Vs 6-8yrs		***6-8 Vs 8-10yrs***		***4-6 Vs 8-10yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
F2mag(Hz)	-2.69	0.00**	-0.90	0.37	-3.578	0.00**
F2rate (/s)	-1.59	0.11	-1.72	0.09	-2.292	0.02*
F2aver(Hz)	-2.17	0.03*	-2.30	0.02*	-.059	0.95
F2min(Hz)	-3.10	0.00**	-0.43	0.67	-2.780	0.00*

**P<0.05, **p<0.01*

Effect of age group in males for F2 transition

Male participants were compared using Kruskal Wallis test for F2 transition. The results showed that only F2 magnitude (Hz) and F2 maximum (Hz) showed a significant overall age group effect. Since there is a significant difference between the age groups in males for the parameters F2magn and F2max, pair wise comparison using Mann- Whitney U test was carried out to find out the individual age group difference. Table 4.32 represents the mean, Standard Deviation (SD), Chi square value and p-value of males across age group for F2 transition

Table 4.32: *Mean, SD, Chi square value and p-value of males across age group for F2 transition*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
F2magn (Hz)	4-6	529 (170.6)	9.71	0.00**
	6-8	364 (118.7)		
	8-10	397 (120.9)		
F2rate (/s)	4-6	1.72 (0.71)	2.78	0.25
	6-8	2.00 (1.61)		
	8-10	1.95 (0.95)		
F2reg (%)	4-6	58.70 (13.56)	0.00	0.99
	6-8	59.12 (12.82)		
	8-10	58.89 (11.5)		
F2aver (Hz)	4-6	4616 (206.42)	2.14	0.34
	6-8	4717 (256.0)		
	8-10	4660 (231.3)		
F2min (Hz)	4-6	2685 (695.3)	4.68	0.10
	6-8	3243 (623)		
	8-10	3144 (637)		
F2max (Hz)	4-6	5873 (442.3)	7.09	0.03*
	6-8	6089 (684)		
	8-10	6643 (917.86)		

**P<0.05, **p<0.01*

The results of Mann Whitney u test done in order to compare the between age effect is mentioned in table 4.33.

Comparison between individual age groups for F2 transition

The table 4.33 shows the Z- value and p-value of individual age groups for F2 transition. It can be noted that in the comparison between higher age group (4-6y versus 8-10y) both F2magn and F2max has shown a significant difference. There were no parameters observed as significantly different in the comparison 6-8 versus 8-10 age groups.

Table 4.33*: Z- value and p-value of individual age groups for F2 transition*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
F2magn	-2.80	0.00**	-0.73	0.47	-2.47	0.01*
F2max	-1.14	0.27	-1.72	0.09	-2.51	0.01*

**P<0.05, **p<0.01*

Effect of age group in females for F2 transition

Table 4.34 represents the mean, Standard Deviation (SD), Chi square value and p-value for female group across different age groups. From this table it can be observed that, parameters like F2 magnitude and F2 minimum were significantly different across age groups for females. On observation of the table it can be noted that the F2 rate is increasing with increase in age and a negative correlation for F2magn.

Table 4.34: *Mean, SD, Chi square value and p-value of females across age group for F2 transition*

Parameter	Age group(yrs)	Mean (SD)	*Chi Square value*	*P- value*
F2magn (Hz)	4-6	490 (150.16)	8.64	0.01*
	6-8	446 (135.8)		
	8-10	353 (94.86)		
F2rate (/s)	4-6	1.71 (1.42)	4.37	0.11
	6-8	1.62 (0.48)		
	8-10	1.84 (.610		
F2reg (%)	4-6	59.23(11.96)	0.85	0.65
	6-8	64.89(14.30)		
	8-10	64.00(15.28)		
F2aver (Hz)	4-6	4627 (234)	5.99	0.05
	6-8	4810 (241)		
	8-10	4561 (261.5)		
F2min (Hz)	4-6	2682 (515)	7.28	0.03*
	6-8	3181(599)		
	8-10	3146 (612.0)		
F2max (Hz)	4-6	6082 (517)	0.11	0.95
	6-8	6210 (1000)		
	8-10	6238 (868.8)		

**P<0.05, **p<0.01*

Since there was a significant difference for females across age group pair wise comparison was carried out for F2magn and F2min.

Comparison between individual age group for F2 transition

Table 4.35: *Z- value and p-value of individual age group for F2 transition*

	4-6 Vs 6-8yrs		***6-8 Vs 8-10***		***4-6 Vs 8-10***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P-value***	***Z- value***	***P- value***
F2magn (Hz)	-0.76	0.46	-2. 10	0.04*	-2.80	0.00**
F2min (Hz)	-2.30	0.02*	-0.29	0.78	-0.19	0.87

**P<0.05, **p<0.01*

Effect of gender for F2 transition

Table 4.36 indicates the Mean, Standard Deviation (SD), Z-value and P-value for gender effect. All the parameters showed no significant difference for gender comparison. Hence, further comparison of gender across age group was not carried out.

Table 4.36*: Mean, SD, Z- value and p-value between gender for intonation stimulability*

Parameter	Gender	Mean(SD)	***Chi Square value***	***P- value***
F2magn (Hz)	Male	430 (153.51)	-0.07	0.95
	Female	430 (138.74)		
F2rate (/s)	Male	1.89 (1.05)	-1.16	0.25
	Female	1.73(0.92)		
F2reg (%)	Male	58.91 (12.39)	-1.26	0.21
	Female	62.71 (13.84)		
F2aver (Hz)	Male	4665 (230.62)	-0.13	0.89
	Female	4666 (262.9)		
F2min (Hz)	Male	3024 (683.5)	-0.39	0.67
	Female	3003 (609.1)		
F2max (Hz)	Male	6202 (765.9)	-0.48	0.63
	Female	6176 (805.6)		

**P<0.05, **p<0.01*

3) Voice and tremor parameter

Effect of age group on voice and tremor parameters

Table 4.37 shows the Mean, Standard Deviation (SD), Chi square value and p-value for voice and tremor parameters across all age groups. From the results it can be inferred that all of the voice parameters like Fundamental frequency (F0), Average pitch period (T0), Highest Fundamental frequency (Fhi), Standard Deviation of fundamental frequency (STD), Coefficient of variation of Fundamental frequency (vF0), Coefficient of variation of Amplitude (vAm) has shown a significant age group difference except for the parameter lowest fundamental frequency (Flo). Under tremor parameter, only two of the parameters, rate of amplitude tremor (Ratr), Periodicity of amplitude tremor (Patr) was found to be showing significant difference. The mean value for parameters like F0, Fhi, Flo, STD, vAm, Rftr was found to be decreasing with an increase in age.

Table 4.37: *Mean, SD, Chi square value and p-value of age group difference for voice and tremor parameter*

	Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P-value***
Voice parameters	F0 (Hz)	4-6	287.78(37.70)	7.79	0.02*
		6-8	279.7(26.40)		
		8-10	264.9(38.43)		
	T0 (ms)	4-6	3.55(0.63)	7.76	0.02*
		6-8	3.60(0.37)		
		8-10	3.88(0.80)		
	Fhi (Hz)	4-6	298.6(38.37)	9.06	0.01*
		6-8	287.6(26.65)		
		8-10	273.5(39.08)		
	Flo (Hz)	4-6	275.4(37.13)	5.66	0.06
		6-8	271.23(26.16)		
		8-10	256.55(36.45)		
	STD (Hz)	4-6	4.74(1.52)	13.00	0.00**
		6-8	3.58(1.79)		
		8-10	3.57(1.45)		
	vF0 (%)	4-6	1.66(0.54)	12.54	0.00**
		6-8	1.29(0.71)		
		8-10	1.35(0.51)		

	vAm (%)	4-6	15.22(7.44)	10.70	0.00**
		6-8	11.32(7.19)		
		8-10	9.63(4.94)		
Tremor parameters	Mftr (%)	4-6	0.40(0.15)	2.08	0.35
		6-8	0.38(0.24)		
		8-10	0.40(0.12)		
	Matr (%)	4-6	3.44(1.25)	2.25	0.32
		6-8	3.79(1.19)		
		8-10	3.69(1.10)		
	Rftr (Hz)	4-6	0.55(1.02)	0.20	0.90
		6-8	0.24(0.74)		
		8-10	0.22(0.70)		
	Ratr (Hz)	4-6	1.70(2.66)	8.85	0.01*
		6-8	2.25(2.32)		
		8-10	3.61(2.53)		
	Pftr (%)	4-6	2.93(11.85)	0.23	0.89
		6-8	3.49(10.79)		
		8-10	2.70(8.42)		
	Patr (%)	4-6	13.36(20.67	8.44	0.01*
		6-8	18.66(19.35)		
		8-10	29.08(22.60)		

**P<0.05, **p<0.01*

As the parameters like F0, T0, Fhi, STD, vF0, vAm, Ratr and was found to be showing a significant age group difference, the parameters were subjected to pair wise comparison using Mann- Whitney U test.

Comparison between individual age groups on voice and tremor parameters

Table 4.38 explains the pair wise comparison using Mann-Whitney U test between different age groups of those parameters which showed a significant difference across age group. In the comparison between the age groups 4-6y versus 6-8y, the parameter vF0, STD and vAm showed a significant difference. When the age groups 6-8y versus 8-10y were compared only the parameter Ratr showed a significant difference. Finally when 4-6y versus 8-10 years was subjected to pair wise comparison, it was found that all the parameters of both voice and tremor showed a significant difference.

Table 4.38: *Z- value and p-value of individual age groups for Voice and Tremor parameter*

	4-6 and 6-8 yrs		***6-8 and 8-10 yrs***		***4-6 and 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
F0 (Hz)	-1.00	0.31	-1.86	0.06	-2.68	0.00**
T0 (ms)	-0.99	0.31	-1.86	0.06	-2.68	0.00**
Fhi (Hz)	-1.62	0.10	-1.52	0.12	-2.92	0.00**
STD (Hz)	-3.00	0.00**	-0.44	0.66	-3.21	0.00**
vF0 (%)	-3.13	0.00**	-1.35	0.18	-2.71	0.00**
vAm (%)	-2.37	0.01*	-1.17	0.24	-3.01	0.00**
Ratr (Hz)	-1.04	0.29	-2.23	0.03*	-2.66	0.00**
Patr (%)	-1.29	0.19	-1.80	0.07	-2.78	0.00**

$*P<0.05$, $**p<0.01$

Effect of age group in males on voice and tremor parameters

Kruskal Wallis test was used to compare males across age groups for voice and tremor parameter. It can be observed that all the voice parameters except vAm have shown a significant age group effect. None of the tremor parameters showed a significant difference across age group. It can be observed that there is a gradual decrease in the mean values of all voice parameters like F0, Fhi, Flo, STD, vF0, vAm except T0 with an increase in age. Under tremor parameters, mean values for Mftr, Rftr, Pftr were found to be decreasing and parameters such as Raftr and Patr were observed to be increasing with age though there is no significant difference.

Table 4.39: *Mean, SD, Chi square value and p-value of males across age group for Voice and tremor parameters*

	Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value***	***P- value***
Voice parameters	F0 (Hz)	4-6	296.9(21.19)	16.11	0.00**
		6-8	278.6(24.31)		
		8-10	250.8(41.60)		
	T0 (ms)	4-6	3.38(0.23)	16.05	0.00**
		6-8	3.62(0.33)		
		8-10	4.14(1.03)		
	Fhi (Hz)	4-6	308.8(20.40)	18.50	0.00**
		6-8	286.4(22.53)		
		8-10	258.3(42.61)		
	Flo (Hz)	4-6	281.8(24.76)	10.37	0.00**
		6-8	269.3(25.44)		
		8-10	243.6(40.91)		
	STD (Hz)	4-6	5.42(1.37)	15.17	0.00**
		6-8	3.61(2.06)		
		8-10	3.16(1.06)		
	vF0 (%)	4-6	1.84(0.52)	11.60	0.00**
		6-8	1.33(0.89)		
		8-10	1.27(0.36)		
	vAm (%)	4-6	15.12(6.92)	4.47	0.10
		6-8	11.12(5.96)		
		8-10	10.51(5.27)		
Tremor parameters	Mftr (%)	4-6	0.50(0.16)	3.77	0.15
		6-8	0.45(0.32)		
		8-10	0.42(0.12)		
	Matr (%)	4-6	3.90(1.29)	1.07	0.59
		6-8	4.00(1.08)		
		8-10	3.75(1.15)		
	Rftr (Hz)	4-6	0.51(1.43)	0.00	0.99

	6-8	0.35(0.93)		
	8-10	0.32(0.87)		
Ratr (Hz)	4-6	1.71(2.57)	3.08	0.21
	6-8	1.92(2.23)		
	8-10	3.23(2.74)		
Pftr (%)	4-6	5.87(16.50)	0.00	0.99
	6-8	4.37(11.69)		
	8-10	3.29(8.88)		
Patr (%)	4-6	13.00(19.67)	3.90	0.14
	6-8	13.95(17.68)		
	8-10	26.59(22.62)		

**P<0.05, **p<0.01*

Since there is a significant difference between the age groups in males for the parameters F0, T0, Fhi, Flo, STD, and vF0, pair wise comparison using Mann-Whitney U test was carried out to find out the individual age group difference.

Comparison between individual age groups on voice and tremor parameters

Table 4.40 represents the pair wise comparison using Mann-Whitney U test between different age groups of those parameters which showed a significant overall age group effect. When age groups 4-6y versus 6-8y, parameters such as Fhi, STD and vF0 was found to be significantly different. In the comparison between the age groups 6-8y versus 8-10y, the parameters like F0, T0 and Fhi was found to be significantly different. It can be observed that when the age groups 4-6y and 8-10y were compared, all the parameters were found to be significantly different.

Table 4.40*: Z- value and p-value of individual age groups for voice and tremor parameters*

	4-6 and 6-8 yrs		***6-8 and 8-10 yrs***		***4-6 and 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
F0 (Hz)	-1.84	0.7	-2.34	0.01*	-3.88	0.00**
T0 (ms)	-1.84	0.07	-2.32	0.01*	-3.88	0.00**

Fhi (Hz)	-2.47	0.01*	-2.10	0.03*	-4.13	0.00**
Flo (Hz)	-1.26	0.21	-1.92	0.05	-3.17	0.00**
STD (Hz)	-2.88	0.00**	-0.10	0.93	-3.79	0.00**
vF0 (%)	-2.63	0.00**	-1.10	0.28	-3.15	0.00**

*P<0.05, **p<0.01

Effect of age group in females on voice and tremor parameters

Table 4.41 shows Mean, Standard Deviation (SD), Chi square value and *p-value* for female group across different age groups. From this table it can be observed that none of the parameters were significantly different across age groups for females. So further pair wise comparison was not carried out.

Table 4.41: *Mean, SD, Chi square value and p-value of females across age group for voice and tremor parameter*

	Parameter	Age group(yrs)	Mean (SD)	*Chi Square value*	*P-value*
Voice parameters	F0 (Hz)	4-6	278.6(48.13)	0.28	0.87
		6-8	18.01(19.54)		
		8-10	279.1(29.98)		
	T0 (ms)	4-6	3.71(0.84)	0.28	0.87
		6-8	3.60(0.42)		
		8-10	3.62(0.38)		
	Fhi (Hz)	4-6	288.3(49.08)	0.03	0.98
		6-8	288.7(30.99)		
		8-10	288.8(29.16)		
	Flo (Hz)	4-6	269.0(46.43)	0.72	0.70
		6-8	273.0(27.63)		
		8-10	269.4(26.90)		
	STD (Hz)	4-6	4.07(1.39)	1.32	0.51
		6-8	3.56(1.56)		
		8-10	4.00(1.69)		
	vF0 (%)	4-6	1.48(0.50)	1.81	0.40

		6-8	1.25(0.49)		
		8-10	1.44(0.63)		
	vAm (%)	4-6	15.32(8.17)	6.02	0.05
		6-8	11.52(8.45)		
		8-10	8.76(4.60)		
Tremor parameters	Mftr (%)	4-6	0.31(0.06)	3.32	0.19
		6-8	0.32(0.12)		
		8-10	0.39(0.13)		
	Matr (%)	4-6	3.00(1.06)	3.52	0.17
		6-8	3.58(1.30)		
		8-10	3.63(1.10)		
	Rftr (Hz)	4-6	0.00(0.00)	1.02	0.6
		6-8	0.13(0.51)		
		8-10	0.13(0.50)		
	Ratr (Hz)	4-6	1.70(2.85)	5.67	0.06
		6-8	2.58(2.44)		
		8-10	4.00(2.32)		
	Pftr (%)	4-6	5.87(16.50)	1.02	0.60
		6-8	2.61(10.13)		
		8-10	2.12(8.22)		
	Patr (%)	4-6	13.71(22.31)	4.73	0.09
		6-8	23.38(20.39)		
		8-10	31.59(23.10)		

**P<0.05, **p<0.01*

Effect of gender

This table shows the Mean, standard deviation (SD), Z value and P-value for gender effect. It can be noted that only two tremor parameters such as Mftr, Matr was found to be significantly different. It can be observed that the fundamental frequency is almost pair wise comparison was done for significant parameters.

Table 4.42*: Mean, SD, Z- value and p-value between gender for voice and tremor parameters*

Parameter	Gender	Mean (SD)	*Chi Square value*	*P- value*
F0 (Hz)	Male	275.4(35.35)	-0.09	0.93
	Female	279.4(35.98)		
T0 (ms)	Male	3.71(0.70)	-0.09	0.93
	Female	3.65(0.57)		
Fhi (Hz)	Male	284.5(36.19)	-0.16	0.88
	Female	288.6(36.64)		
Flo (Hz)	Male	264.9(34.52)	-0.50	0.62
	Female	270.5(34.10)		
STD (Hz)	Male	4.06(1.82)	-0.23	0.82
	Female	3.88(1.53)		
vF0 (%)	Male	1.48(0.67)	-0.38	0.70
	Female	1.39(0.54)		
vAm (%)	Male	12.25(6.30)	-0.99	0.32
	Female	11.87(7.62)		
Mftr (%)	Male	0.46(0.22)	-3.16	0.00**
	Female	0.34(0.11)		
Matr (%)	Male	3.88(1.16)	-2.02	0.04*
	Female	3.40(1.17)		
Rftr (Hz)	Male	0.40(1.09)	-1.57	0.11
	Female	0.09(0.40)		
Ratr (Hz)	Male	2.29(2.56)	-0.96	0.34
	Female	2.76(2.67)		
Pftr (%)	Male	4.51(12.51)	-1.42	0.16
	Female	1.58(7.45)		
Patr (%)	Male	17.85(20.61)	-1.09	0.27
	Female	22.89(22.69)		

$*P<0.05$, $**p<0.01$

4) Intonation stimulability

Effect of age group on intonation stimulability

Table 4.43 shows the Mean, Standard Deviation, Chi square value and p-value for the parameter s of intonation stimulability across all age groups. The outcomes indicated that the majority of the parameters have a significant age group differently except rvAm parameter. The Mean value and Standard Deviation (SD) for parameters like rF0, rFhi, rvAm was found to be decreasing with increase in age. The mean value of rT0 is found to be increasing with age.

Table 4.43: *Mean, SD, Chi square value and p-value of age group difference for intonation stimulability*

Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value***	***P- value***
	4-6	288.5(33.72)	8.65	
rF0 (Hz)	6-8	283.0(30.46)		0.01*
	8-10	265.0(31.38)		
rT0 (ms)	4-6	3.51(0.45)	8.65	0.01*
	6-8	3.57(0.43)		
	8-10	3.68(0.41)		
rFhi (Hz)	4-6	386.2(28.20)	8.13	0.02*
	6-8	366.6(37.29)		
	8-10	360.7(40.52)		
rFlo (Hz)	4-6	215.1(47.95)	9.08	0.01*
	6-8	225.1(40.61)		
	8-10	201.7(49.15)		
rSTD (Hz)	4-6	39.28(16.74)	6.43	0.04*
	6-8	31.25(12.33)		
	8-10	38.71(15.37)		
rvF0 (%)	4-6	14.16(7.66)	9.00	0.01*
	6-8	11.18(4.89)		
	8-10	15.03(7.12)		
rvAm (%)	4-6	42.06(11.72)	3.01	0.22
	6-8	38.77(10.52)		
	8-10	36.02(6.64)		

$*P<0.05$, $**p<0.01$

Since there is a significant difference between the age groups for the parameters rF0, rT0, rFhi, rFlo, rSTD, rvF0, pair wise comparison was carried out using Mann- Whitney U test.

Comparison between individual age groups on intonation stimulability

Table 4.44 shows the pair wise comparison using Mann-Whitney U test between different age groups of those parameters which showed a significant difference across age group. In the comparison between the age groups 4-6y versus 6-8y, the parameters like rFhi and rSTD showed a significant difference. When the age groups 6-8y versus 8-10y were compared all the parameters (rF0, rT0, rFlo, rSTD, rvF0) except rFhi showed a significant difference. When the age groups of 4-6y versus 8-10y were subjected to pair wise comparison, except two parameters (rFhi and rSTD) all the other parameters (rF0, rT0, rFhi, rFlo) showed a significant difference.

Table 4.44: *Z- value and p-value of individual age groups for intonation stimulability*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
rF0(Hz)	-0.69	0.48	-2.28	0.02*	-2.69	0.01*
rT0 (ms)	-0.69	0.48	-2.28	0.02*	-2.69	0.01*
rFhi(Hz)	-2.12	0.03*	-0.79	0.42	-2.64	0.01*
rFlo (Hz)	-0.532	0.595	-2.77	0.00**	-2.36	0.02*
rSTD(%)	-2.26	0.02*	-2.10	0.04*	-0.20	0.83
rvF0(%)	-1.77	0.08	-2.87	0.00**	-1.43	0.15

**P<0.05, **p<0.01*

Effect of age group in males on intonation stimulability

Males were compared using Kruskal Wallis test for intonation stimulability. The results showed that the majority of the parameters have a significant overall age group effect. The mean value and Standard Deviation (SD) for parameters like rF0, rFhi was found to be decreasing with age.

Table 4.45: *Mean, SD, Chi square value and p-value of males across age group for intonation stimulability*

Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value***	***P value***
	4-6	289 (28.930	10.95	0.00**
rF0(Hz)	6-8	287 (29.32)		
	8-10	255 (30.05)		
rT0 (ms)	4-6	3.48(0.34)	10.95	0.00**
	6-8	3.51(0.41)		
	8-10	3.97(0.52)		
rFhi(Hz)	4-6	389 (26.14)	7.46	0.02*
	6-8	366 (44.78)		
	8-10	349 (41.47)		
rFlo(Hz)	4-6	203 (50.42)	6.26	0.04*
	6-8	223 (45.37)		
	8-10	176 (53.00		
rSTD(Hz)	4-6	43.11(17.97)	4.53	0.10
	6-8	32.01(13.93)		
	8-10	39.19(15.7)		
rvF0(%)	4-6	15.19(7.16)	6.84	0.03*
	6-8	11.13(5.17)		
	8-10	15.78(7.23)		
rvAm(%)	4-6	40.07(9.2)	1.40	0.49
	6-8	41.23(12.34)		
	8-10	35.20(6.63)		

**P<0.05, **p<0.01*

Since there is a significant difference between the age groups in males for the parameters rF0, rT0 and for rFhi, rFlo, rvF0 pairwise comparison using Mann-Whitney U test was carried out to find out the individual age group difference.

Comparison between individual age groups on intonation stimulability

Table 4.46 shows z-value and p-value for different age groups of those parameters which showed a significant overall age group effect. In the comparison between the age groups 4-6y versus 6-8y, only the parameter rvF0 was found to be significantly different. When the age groups 6-8y versus 8-10y were compared all the parameters (rF0, rT0, rFlo, rvF0) except rFhi showed a significant difference. There was a significant difference for the parameters such as rF0, rT0, rFhi when the age groups of 4-6y versus 8-10y were subjected to pair wise comparison.

Table 4.46***:*** *Z- value and p-value of individual age groups for intonation stimulability*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10yrs***		***4-6 Vs 8-10yrs***	
Parameter	***Z- value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
rF0(hz)	-0.18	0.87	-3.05	0.00**	-2.63	0.01*
rT0(ms)	-0.18	0.87	-3.05	0.00**	-2.63	0.01*
rFhi(Hz)	-1.68	0.09	-1.34	0.18	-2.55	0.01*
rFlo(Hz)	-0.93	0.36	-2.34	0.01*	-1.72	0.08
rvF0(%)	-2.13	0.03*	-2.30	0.02*	-0.60	0.56

**P<0.05, **p<0.01*

Effect of age group in females on intonation stimulability

Table 4.47 represents mean, Standard Deviation (SD), Chi square value and p-value for female group across different age groups. From this table it can be observed that none of the parameters were significantly different across age groups for females. So further pairwise comparison was not carried out.

Table 4.47: *Mean, SD, Chi square value and p-value of females across age group for intonation stimulability*

Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value***	***P value***
rF0(Hz)	4-6	287.2(38.92)	1.38	0.50
	6-8	278.23(31.81)		
	8-10	274.94(30.4)		
rT0 (ms)	4-6	3.55(0.55)	1.38	0.50
	6-8	3.64(0.45)		
	8-10	3.68(0.41)		
rFhi(Hz)	4-6	383.05(30.68)	2.04	0.36
	6-8	366.2(29.58)		
	8-10	372.11(37.46)		
rFlo(Hz)	4-6	226.40(44.15)	4.06	0.13
	6-8	227.29(36.73)		
	8-10	201.73(49.15)		
rSTD(Hz)	4-6	35.46(15.05)	2.36	0.30
	6-8	30.49(10.93)		
	8-10	38.24(15.58)		
rvF0(%)	4-6	13.14(8.25)	3.04	0.21
	6-8	11.23(4.78)		
	8-10	14.28(7.17)		
rvAm(%)	4-6	44.06(13.82)	2.54	0.28
	6-8	36.32(8.02)		
	8-10	36.83(6.79)		

**P<0.05, **p<0.01*

Effect of gender on intonation stimulability

Table 4.48 shows the mean, standard deviation, Z-value and P-value of gender effect. Across all the parameters no significant difference was observed for gender comparison.

Table 4.48*: Mean, SD, Z- value and p-value between gender for intonation stimulability*

Parameter	**Gender**	***Mean (SD)***	***Z- value***	***P- value***
rF0(Hz)	Male	277.62(32.99)	-0.573	0.567
	Female	280.13(33.56)		
rT0(ms)	Male	3.65(0.48)	-0.58	0.56
	Female	3.62(0.47)		
rFhi(Hz)	Male	368.56(40.99)	-0.55	0.57
	Female	373.8(32.76)		
rFlo(Hz)	Male	201.01(52.33)	-1.63	0.10
	Female	218.4(44.29)		
rSTD(Hz)	Male	38.10(16.27)	-0.85	0.39
	Female	34.73(14.06)		
rvF0(%)	Male	14.03(6.77)	-0.56	0.57
	Female	12.88(6.85)		
rvAm(%)	Male	38.83(9.82)	-0.07	0.94
	Female	39.07(10.43)		

**P<0.05, **p<0.01*

5) Syllabic rate

Effect of age group on syllabic rate

Table 4.49 represents the mean, Standard Deviation, Chi square value and p-value for syllabic rate parameters across all age groups. From the results it can be implied that all the parameters of syllabic rate like parameters like Average syllabic rate (SLrate), Average pause duration (SLpdur), Percentage speaking time (SLspk), Percentage pause time (SLpau) has shown a significant age group difference except for the parameter Average syllabic duration (SLsdur). The mean value for parameters like SLrate and SLspk was observed to be increasing with age. A decrease in the mean value for the parameters SLpdur and SLpau was also observed with an increase in age.

Table 4.49: *Mean, SD, Chi square value and p-value of age group difference for Syllabic rate parameters*

Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value***	***P- value***
SLrate (/s)	4-6	3.44 (0.53)	9.30	0.01*
	6-8	3.94(0.88)		
	8-10	4.2(1.27)		
SLsdur (ms)	4-6	239 (0.66)	2.40	0.30
	6-8	207(73.90)		
	8-10	242 (80.15)		
SLpdur (ms)	4-6	206 (166)	13.95	0.00**
	6-8	195 (127)		
	8-10	98.36(113)		
SLspk (%)	4-6	75.37 (20.18)	15.13	0.00**
	6-8	78.70 (21.88)		
	8-10	93.91 (6.67)		
SLpau (%)	4-6	24.62 (20.17)	15.13	0.00**
	6-8	21.29 (21.88)		
	8-10	6.08 (6.670		

**P<0.05, **p<0.01*

The significant parameters such as SLrate, SLpdur, SLspk, SLpau were subjected to pair wise comparison using Mann- Whitney U test.

Comparison between individual age groups on syllabic rate

The table 4.50 shows the pair wise comparison using Mann-Whitney U test between different age groups of those parameters which showed a significant difference across age group .When the age groups 4-6y versus 6-8y were compared, the parameter SLrate showed a significant difference. It can be noted that when the age groups 6-8y versus 8-10y were subjected to pair wise comparison, compared the parameters like SLpdur, SLspk and SLpau showed a significant difference. All the parameters which have undergone pair wise comparison have shown a significant difference when the age groups 4-6y and 8-10y were compared.

Table 4.50: *Z- value and p-value of individual age groups for Syllabic rate parameters*

	4-6 Vs 6-8 yrs		***6-8 Vs 8-10yrs***		***4-6 Vs 8-10yrs***	
Parameter	***Z –value***	***P- value***	***Z- value***	***P- value***	***Z- value***	***P- value***
SLrate (/s)	-2.12	0.03*	-0.75	0.46	-2.96	0.00**
SLpdur (ms)	-0.37	0.71	-3.06	0.00**	-3.43	0.00**
SLspk (%)	-0.19	0.84	-2.99	0.00**	-3.73	0.00**
SLpau (%)	-0.19	0.84	-2.99	0.00**	-3.73	0.00**

**P<0.05, **p<0.01*

Effect of age group in males on syllabic rate

Table 4.51 shows the mean, Standard Deviation (SD), Chi square value and p-value for syllabic rate parameters of males across age groups. It can be implied that all the parameters other than SLsdur has shown a significant age group effect. Overall, it can be noted that there is an increase in the mean value of the parameters like SLrate and SLspk as the age progresses. The mean values of parameters such as SLpdur and SLpau was found to decrease with age for male group.

Table 4.51: *Mean, SD, Chi square value and p-value of males across age group for Syllabic rate parameters*

Parameter	**Age group(yrs)**	**Mean (SD)**	***Chi Square value***	***P- value***
SLrate (/s)	4-6	3.34 (0.66)	8.36	0.01*
	6-8	4.02 (0.78)		
	8-10	4.60 (1.45)		
SLsdur (ms)	4-6	239 (101.5)	1.21	0.54
	6-8	195 (74.95)		
	8-10	220 (62.95)		
SLpdur (ms)	4-6	267 (209)	11.37	0.00**
	6-8	201.9 (125)		
	8-10	103.0 (127)		
SLspk (%)	4-6	75.37 (20.17)	10.49	0.00**
	6-8	75.42 (24.23)		
	8-10	93.44 (7.31)		
SLpau (%)	4-6	24.62 (20.17)	10.49	0.00**
	6-8	20.58 (24.23)		
	8-10	6.55 (7.31)		

**P<0.05, **p<0.01*

All the significant parameters except SLsdur were subjected to Mann-Whitney U test to find out the individual age group difference.

Comparison between individual age groups on syllabic rate

Table 4.52 shows the z-value and p-value of those parameters which showed a significant overall age group effect for males. When age groups 4-6y versus 6-8y were compared only the parameter SLrate was found to be significantly different. In the comparison between the age groups 6-8y versus 8-10y, the parameters like SLpdur, SLspk and SLpau were observed to be significantly different. All the parameters were found to be showing a significant difference when the age groups 4-6y and 8-10y were subjected to pair wise comparison.

Table 4.52*: Z- value and p-value of individual age groups for Syllabic rate parameters*

Parameter	***4-6 Vs 6-8 yrs***		***6-8 Vs 8-10 yrs***		***4-6 Vs 8-10 yrs***	
	Z- value	***P- value***	***Z- value***	***P- value***	***Z- value***	***P -value***
SLrate (/s)	-2.34	0.01*	-0.89	0.39	-2.50	0.01*
SLpdur (ms)	-0.77	0.46	-2.33	0.02*	-3.31	0.00**
SLspk (%)	-0.43	0.68	-2.37	0.02*	-3.15	0.00**
SLpau (%)	-0.43	0.68	-2.37	0.02*	-3.15	0.00**

**P<0.05, **p<0.01*

Effect of age group in females on syllabic rate

The table 4.53 shows mean, SD, Chi square value and *p-value* for female group across different age groups. It was inferred that none of the parameters were significantly different across age groups for females. So further pairwise comparison across age group was not carried out.

Table 4.53: *Mean, SD, Chi square value and p-value of females across age group for Syllabic rate parameters*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value (λ)***	***P- value***
SLrate (/s)	4-6	3.54(0.35)	1.93	0.38
	6-8	3.87(1.01)		
	8-10	3.84(0.99)		
SLsdur (ms)	4-6	247 (36.04)	0.64	0.72
	6-8	220 (73.21)		
	8-10	264 (91.17)		
SLpdur (ms)	4-6	144 (71.27)	5.04	0.08
	6-8	189 (134.2)		
	8-10	93.70(102.6)		
SLspk (%)	4-6	87.09(11.62)	5.05	0.08
	6-8	81.98(19.54)		

	8-10	94.37(6.17)		
SLpau (%)	4-6	12.90(11.62)	5.05	0.08
	6-8	18.01(19.54)		
	8-10	5.62(6.17)		

*P<0.05, **p<0.01

Effect of gender on syllabic rate

Table 4.54 indicates the mean, Standard deviation (SD), Z value and P-value for gender effect. It can be implied only the parameter SLsdur has shown a significant difference. Overall it was observed that the mean values for syllabic rate, average pause duration, percentage pause time was higher for males when compared to females. Pair wise comparison was done for significant parameters.

Table 4.54*: Mean, SD, Z- value and p-value between gender for Syllabic rate parameters*

Parameter	**Age group(yrs)**	**Mean(SD)**	***Chi Square value***	***P- value***
SLrte	Male	3.99(1.12)	-0.77	0.44
	Female	3.75 (0.83		
SLsdur	Male	218.4(81.68)	-2.02	0.04*
	Female	244.0(71.48)		
SLpdur	Male	190.9(169.7)	-1.38	0.17
	Female	142.6(110.7)		
SLspk	Male	81.41(20.18)	-1.60	0.11
	Female	87.81(14.24)		
SLpau	Male	18.58(20.18)	-1.60	0.11
	Female	12.18(14.24)		

Summary of results

Diadochokinetic rate

- For all the DDK tasks (AMR) the average DDK rate increased with age.
- For majority of the parameters under DDK had a significant age effect.
- No significant gender effect was noticed.
- Differences in the mean values of the DDK parameters were less in 4-6 versus 6-8 age group comparison when compared to 6-8y versus 8-10y
- For the task /pataka/- the average DDK rate increase with age and also the average DDK period was found to be decreasing with age. All the age group comparison (4-6y versus 6-8y, 6-8y versus 8-10y & 4-6y versus 8-10y) has shown a significant difference.

F2 transition

- F2 magnitude showed a reduction in the mean value with an increase in age.
- F2 rate was found to be increasing with age
- No gender difference was noticed

Voice and tremor parameter

- The mean value of voice parameters were found to be decreasing with age
- An increase in the mean values of tremor parameters was noticed with age.
- Majority of voice parameters showed a significant different across age groups. But no significant difference was noticed in case of tremor parameters.
- There were no much of difference seen between 4-6 and 6-8 years. But there was a greater difference noticed between 4-6 and 8-10 year groups.

Intonation stimulability

- Most of the parameters under intonation stimulability have shown a significant difference.
- Most of the frequency parameters were found to be decreasing with age in which greater changes were noticed between 6-10 years.
- No significant gender effect was noticed**.**

Syllabic rate

- Syllabic rate increased with age and similar trend was seen in only males and only females group.
- Syllabic duration and pause time was found to be decreasing with age.
- Age group differences were more evident in 4-6y versus 8-10y comparison.
- Overall there was no significant gender effect noticed.

Reliability Check

Test retest reliability was done only for parameters like DDK and voice and tremor parameters. For reliability check one of the three repetition / tokens (excluding that considered for the formulation of reference data) was used. It was found that most of the parameters has shown an alpha value greater than 0.60. Table 4.55 shows the Cronbach's alpha value for the parameters of DDK and voice and tremor.

Table 4.55**:** *Cronbach's alpha for the parameters DDK and voice and tremor parameter*

Parameters	Cronbach's alpha
Diadochokinetic Rate	
DDKavp, ms	0.68
DDKavr, /s	0.78
DDKsdp, ms	0.77
DDKcvp, %	0.62
DDKjit, %	0.49
DDKavi, dB	0.62
DDKsdi, dB	0.50
DDKcvi, %	0.58
DDKmxa, dB	0.57
DDKava, dB	0.67
DDKsla, dB	0.47
Voice and tremor parameter	
F0, Hz	0.70
T0, ms	0.70
Fhi, Hz	0.72
Flo, Hz	0.50
STD, Hz	0.42
vF0, %	0.20
vAm, %	0.56
Matr, %	0.87
Ratr, Hz	0.54
Patr, %	0.77

Normative Score for MSP measures

Table 4.56 represents the normative table for children in the age range of 4 to 10 years. Mean values of males and females are not separately mentioned as the data did not show any significant gender effect. Also, the mean values of 4-6 y and 6-8y did not show much difference. However the overall values for each age group is indicated in table 4.56.

Table 4.56: *Normative table for DDK, F2 transition, voice and tremor, intonation stimulability and syllabic rate of 4-10 year age group*

	Parameters	**4-6 years**	**6-8 years**	**8-10 years**
Repetition of /pa/ syllable	DDKavp (ms)	239.05(24.93)	214.64(27.96)	189.99 (14.22)
	DDKavr (/s)	4.22 (0.41)	4.73 (0.56)	5.29 (0.38
	DDKsdp (ms)	76.33 (45.19)	88.22 (49.35)	71.84 (44.09)
	DDKcvp (%)	31.79 (17.85)	41.27 (21.25)	38.74 (25.02)
	DDKjit (%)	7.68 (4.39)	9.11 (5.44)	7.53 (4.64)
	DDKavi (dB)	67.17 (9.83)	68.75 (7.62)	75.20 (5.15)
	DDKsdi (dB)	6.25 (2.89)	5.67(2.46)	5.46 (2.44)
	DDKcvi (%)	9.29 (4.53)	8.26 (3.57)	7.31 (3.38)
	DDKmxa (dB)	77.41 (11.33)	78.54 (8.62)	84.79 (8.30)
	DDKava (dB)	52.89 (8.06)	57.78 (7.96)	63.69 (4.27)
	DDKsla (dB)	61.78 (7.82)	64.18 (6.65)	70.36 (4.45)
Repetition of /ta/ syllable	DDKavp (ms)	263.14(40.28)	216.45(25.65)	193.50 (21.21)
	DDKavr (/s)	3.87 (0.51)	4.68 (0.55)	5.22 (0.52)
	DDKsdp (ms)	61.56 (60.30)	63.53 (44.68)	45.75 (26.33)
	DDKcvp (%)	23.52 (22.36)	28.84 (18.52)	24.23 (14.66)
	DDKjit (%)	6.58 (5.75)	6.03 (4.51)	4.71 (2.51)
	DDKavi (dB)	62.82 (9.13)	67.20 (8.10)	72.95 (4.72)
	DDKsdi (dB)	2.26 (1.47)	3.67 (2.57)	2.58 (1.63)
	DDKcvi (%)	3.62 (2.25)	5.51 (3.82)	3.54 (2.23)
	DDKmxa (dB)	66.27 (9.17)	74.12 (8.68)	77.51 (6.05)
	DDKava (dB)	52.54 (9.23)	57.58 (8.20)	64.30 (4.62)
	DDKsla (dB)	60.09 (8.30)	63.43 (6.64)	69.92 (4.39)

Repetition of /ka/ syllable	DDKavp (ms)	262.66(44.92)	210.24(20.39)	198.41(18.48)
	DDKavr (/s)	3.90 (0.58)	4.80 (0.46)	5.08 (0.74)
	DDKsdp (ms)	73.75 (48.76)	61.73 (44.54)	43.47 (28.76)
	DDKcvp (%)	27.25 (15.58)	29.21 (20.90)	21.74 (14.05)
	DDKjit (%)	7.53 (5.45)	5.68 (4.23)	4.37 (2.94)
	DDKavi (dB)	61.34 (9.59)	65.96 (8.40)	73.36 (4.24)
	DDKsdi (dB)	3.15 (1.75)	3.07 (2.26)	2.44 (1.72)
	DDKcvi (%)	5.14 (2.67)	4.59 (3.15)	3.32 (2.26)
	DDKmxa (dB)	65.99 (9.86)	70.17 (8.91)	77.46 (4.99)
	DDKava (dB)	50.14 (9.53)	55.27 (8.16)	63.33 (4.79)
	DDKsla (dB)	59.00 (8.53)	62.07 (6.15)	69.60 (3.82)
Repetition of /pataka/	DDKavp (ms)	242.07(40.59)	197.44(26.35)	184.81(14.54)
	DDKavr (/s)	4.22 (0.68)	5.15 (0.65)	5.44 (0.44)
	DDKsdp (ms)	103.48(55.48)	105.22(67.62)	85.52 (24.66)
	DDKcvp (%)	41.93 (20.36)	51.41 (25.64)	46.19 (12.67)
	DDKjit (%)	11.08 (5.87)	11.48 (5.49)	9.58 (3.45)
	DDKavi (dB)	63.29 (9.01)	65.83 (6.65)	69.75 (5.15)
	DDKsdi (dB)	7.03 (3.72)	7.48 (3.28)	7.84 (2.86)
	DDKcvi (%)	11.01 (5.39)	11.46 (5.05)	11.26 (3.99)
	DDKmxa (dB)	76.59 (10.88)	79.83 (7.98)	84.06 (6.15)
	DDKava (dB)	48.88 (7.90)	53.45 (7.61)	57.61 (4.94)
	DDKsla (dB)	58.74 (8.54)	61.56 (5.44)	64.54 (5.27)
F2 transition	F2magn (Hz)	509 (159.18)	405 (132.8)	375 (109.1)
	F2rate (/s)	1.71(1.10)	1.81(1.18)	1.90(0.60)
	F2reg (%)	58.97(12.56)	62.00(13.67)	61.45(13.58)
	F2aver (Hz)	4622 (216.9)	4763 (249.2)	4611 (247.8)
	F2min (Hz)	2684 (601.56)	3212 (601.5)	3145 (614.1)
	F2max (Hz)	5977 (517.80)	6149 (844)	6440 (902)

voice and tremor	F0 (Hz)	287.78(37.70)	279.7(26.40)	264.9(38.43)
	T0 (ms)	3.55(0.63)	3.60(0.37)	3.88(0.80)
	Fhi (Hz)	298.6(38.37)	287.6(26.65)	273.5(39.08)
	Flo (Hz)	275.4(37.13)	271.23(26.16)	256.55(36.45)
	STD (Hz)	4.74(1.52)	3.58(1.79)	3.57(1.45)
	vF0 (%)	1.66(0.54)	1.29(0.71)	1.35(0.51)
	vAm (%)	15.22(7.44)	11.32(7.19)	9.63(4.94)
	Mftr (%)	0.40(0.15)	0.38(0.24)	0.40(0.12)
	Matr (%)	3.44(1.25)	3.79(1.19)	3.69(1.10)
	Rftr (Hz)	0.55(1.02)	0.24(0.74)	0.22(0.70)
	Ratr (Hz)	1.70(2.66)	2.25(2.32)	3.61(2.53)
	Pftr (%)	2.93(11.85)	3.49(10.79)	2.70(8.42)
	Patr (%)	13.36(20.67	18.66(19.35)	29.08(22.60)
intonation stimulability	rFo (Hz)	288.5(33.72)	283.0(30.46)	265.0(31.38)
	rTo (ms)	3.51(0.45)	3.57(0.43)	3.68(0.41)
	rFhi (Hz)	386.2(28.20)	366.6(37.29)	360.7(40.52)
	rFlo (Hz)	215.1(47.95)	225.1(40.61)	201.7(49.15)
	rSTD (Hz)	39.28(16.74)	31.25(12.33)	38.71(15.37)
	rvFo (%)	14.16(7.66)	11.18(4.89)	15.03(7.12)
	rvAm (%)	42.06(11.72)	38.77(10.52)	36.02(6.64)
syllabic rate	SLrate (/s)	3.44 (0.53)	3.94(0.88)	4.2(1.27)
	SLsdur (ms)	239 (0.66)	207(73.90)	242 (80.15)
	SLpdur (ms)	206 (166)	195 (127)	98.36(113)
	SLspk (%)	75.37 (20.18)	78.70 (21.88)	93.91 (6.67)
	SLpau (%)	24.62 (20.17)	21.29 (21.88)	6.08 (6.67)

CHAPTER 5

DISCUSSION

The current study aimed to produce a normative database of the motor speech skills for children aged between 4 and 10 years and to compare the data across age and gender. The study consisted of ninety subjects in the age range of 4-10 years divided into 3 age groups (4-6 yrs, 6-8yrs and 8-10 yrs). Motor Speech profile (MSP) was used to extract the parameters that are related to speech production. The parameters provided in the software includes Diadochokinetic rate (DDK), F2 transition, Voice and tremor parameter, Intonation stimulability and Syllabic rate. The Kruskal Wallis test was done to see the overall effect of age. Those parameters which showed a significant difference was further taken up for pair wise comparison. Mann-Whitney U test was carried out to know the between gender effect.

Diadochokinetic rate (DDK)

There were four different tasks for DDK which includes the repeated productions of /pa, /ta/, /ka/ and /pataka/ separately.

The outcome of the present study revealed that parameters like Average DDK Period (DDKavp), Average DDK Rate (DDKavr), Average DDK Peak Intensity (DDKavi), Maximum Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), Average Syllabic Intensity (DDKsla) has shown a significant difference across age groups for the task /pa/, /ta/, /ka/ and /pataka/. The results have suggested that there is a significant decrease in the mean values of DDKavp with increase in age. A similar finding was obtained when only males subjects and only females subjects were compared across the different age groups. Overall there was no significant gender effect seen across age groups.

The average DDK rate (DDKavr) has demonstrated a significant difference across the age groups. The data demonstrated that the average rate significantly increased with the progression of age indicating a clear developmental trend.DDK rates increased with age from an average of 4.4 to 5.29 for /pa/, 3.87 to 5.22 for /ta/, 3.90 to 5.08 for /ka/, and 4.22 to 5.44 for /pataka/. There was no gender differences for DDKavp and DDKavr noticed. Parameters like DDKavi, DDKmxa, DDKava, DDKsla also has shown a significant age group difference. The mean values of these parameters were found to be increasing with age. There were no significant gender effects seen for the entire four tasks except for the task /ka/. The mean values for Pertubation of DDK period (DDKjit) was found to be decreasing with age.

As an explanation to the findings regarding the developmental variations in different parameters, Sharkey & Folkins (1985) suggests 3 types of developmental motor processes for speech. One type is regarding the organization of motor system that produces relatively consistent duration parameters by around 4 years of age .Consistent to this explanation, Green, Moore, Higashikawa & Steeve (2000) have indicated the development of lip and jaw coordination for speech integration, differentiation and refinement along with the existence of distinct coordinative constraints on early articulatory movement. The second type of process involves the refinement of the motor organization at intermediate ages. And the final type of process may be related to reduction in the variability of movement duration's studied between children and adult groups. This process may be further involved in precision shaping of the movement patterns.

The findings of these parameters are in consolidation with a previous study done by Wong et al (2011) in 4-18 year old subjects using MSP. Their findings suggested that the DDKavp decreased with age and DDKavr increased with age. The variations in DDKjit were found to be decreasing with age the data also demonstrated that there were no significant difference between males and female across age groups. The results of DDK rate is consistent with another study done by Williams & Stackhouse (1998) in 3-5 year old children , where they found that the accuracy of productions improved with age ,but no significant difference across age was noticed. This could be because of the lesser range of age group. The findings of Canning & Rose (1974) is also in agreement with the present findings indicating that there is a positive correlation for DDK rate with age and adult like rates being achieved by 9-10 years of age. The result is also consistent with the view of Prathanee et al (2003) where they found a significant increase in the DDKrate with age. They also found out that there are gender differences for the production of /pa/, ta/ and /ka/. Boys were found to be faster than girls. The findings of Castro & Wertzner (2011) for 8-10 year old children also indicate the syllabic rates are in agreement with the present study. In consistent with the reduction in DDKavp values with age, Smith (1978) reported that duration of nonsense utterances were 15% longer for four year olds than for adults and 31% longer for 2 year olds than for adults.

The increment in the values of DDKavi, DDKmxa, DDKava, DDKsla could be due to an increased subglottal pressure with age. In a study of nine children 8 – 11 years old, a doubling of subglottal yielded a 10.8 dB increase, similar to adult measures (McAllister, Sundberg 1998).

Second formant transition (F2 transition)

To understand F2 transition, children were asked to produce /i-u/ (vowel-vowel combination) as quickly and accurately as possible. The results showed a significant difference for the parameters such as F2 magnitude (F2magn), F2rate, F2 minimum (F2min) and F2 maximum (F2max). It was noted that there was a reduction in F2magn with the progression in age group. The F2 rate significantly increased with age. There was no influence of gender in all the significant parameters.

As an explanation, the differences between children's and adults' speech may reflect the development of independent speech motor patterns. The data suggest that the realization of the motor programs that underlie anticipatory coarticulation is not innate. Even for lip rounding, there are differences depending on the nature of the segmental elements involved. The results are consistent with the developmental processing involving gradual acquisition and fine tuning of speech motor patterns.

The reduction in the F2 magnitude indicates an increased accuracy and control over the articulators with maturation as the age increases. A similar finding was found in the study done by Wong et al (2011) where they found a reduction in the F2 magnitude with age. There was also a positive correlation found for F2rate with age which supports the findings of the present study. There also found that there was no significant difference between males and females as demonstrated in the present study also. According to the studies done by Turnbaugh, Hoffman, Daniloff and Absher (1985) and Nittrouer (1985), it was found that children seem to coarticulate more than adults indicating a higher magnitude and slower rate of F2 transition in younger age groups. In both the studies, second formant values were lowered in children's speech compared to adult speech. Sereno, Baum, Marean, and Lieberman (1987) found a greater coarticulatory effect in higher age group when compared to children supporting the present study. The findings of the present study is supported by the findings of Hardcastle (2011) suggesting that the extent of coarticulation was significantly lesser in the children than in the adults, providing support for the notion that children's speech production operates with larger units than adults**.**

Voice and tremor parameter

The study the voice and tremor parameter, task the phonation of /a/. A total of 13 sub parameters were studied under voice and tremor parameter. Findings of the present study indicated that voice parameters like Fundamental frequency (F0), Average pitch period (T0), highest fundamental frequency (Fhi), Standard deviation of fundamental frequency (STD), Coefficient of variation of fundamental frequency (vF0), Coefficient of variation of amplitude (vAm). Regarding tremor parameters, Rate of amplitude tremor (Ratr), Periodicity of amplitude tremor (Patr) showed a significant increasing across age groups.

A significant age effect was seen in males for the parameters F0, T0, Fhi, Flo, STD and vF0 while no age effect was seen in females. There was no significant effect of gender observed across age groups. With the progression in age, the mean value for parameters like F0, Fhi, Flo, STD, vAm, was found to be decreasing with a greater change noticed in males compared to females. The mean value of tremor parameters was found to be increasing with age.

The F0 values were found to be slightly higher for females when compared to males. There was a decrement in the F0 values from the age 6 -10 years of age in males in comparison with the female group. Also greater and significant difference were noticed for children in the comparison between 4-6y versus 8-10y when compared to 4-6y versus 6-8y. Females do not demonstrate any significant changes in F0 across age groups. The findings of the present study is in agreement with previous study by Bless et al (1988) done in children aged between 5-11years where a higher fundamental frequency was observed for females than males. A similar finding was indicated by Nicolas et al (2007) where they found a significant decrement in the F0 values in children between 6 and 12 years and the values were found to be lower in boys than in females. Findings of the research conducted by Ting et al (2011) is also consistent with the present study, where they have indicated that females has a significantly higher F0 compared to males in the age range of 8-12 years. Similar to this finding, Hasek & Singh (1980) found that the difference in F0 emerged between males and females only after the age of 7. As an explanation to the present finding, Crelin (1973) suggested that gender differences in laryngeal size and thyroid angle begin to appear by the third year. It could be that these differences in the anatomy are sufficiently great by age seven or eight to account for the fall in F0 observed in the males.

Perry, Ohde & Ashmead (2001) also found that gender differences within the younger age groups (4 year old) were smaller when compared to 8 and 12 years. In contrast to the present study, researchers like Kent (1976), Hollien, Green, and Massey (1994) & Kent and Vorperian (1995) has suggested that there were no difference in F0 between males and females till 12 years. The study also indicated that males had a higher average F0 value than girls.

Another finding of the study is the mean values of most of the tremor parameters were found to be increasing though it was not significant. This could be due to maturational changes in the laryngeal system which leads to variability and instability of vocal fold vibration as children reaches puberty. The changes in the acoustic measures seen in the study correspond to the physiological changes underlying the speech production.

Intonation Stimulability

To study intonation stimulability, a Kannada sentence "Amma ee hannu thumba chanagide" was used as stimulus. The parameters Running Speech Fundamental Frequency(rF0), Running Speech Pitch Period (rT0), Highest Fundamental Frequency(rFhi), Lowest Fundamental Frequency (rFlo), Standard Deviation of Fundamental Frequency (rSTD), Frequency Variability (rvF0) has shown a significant difference across age group. The mean value and SD for parameters like rF0, rFhi, rvAm was found to be decreasing with increase in age. The mean value of rT0 was found to be increasing with age. Most of the frequency parameters were found to be decreasing with age for males in which greater changes were noticed between 6-10 years. There were no significant differences noticed in only female group comparison. There was no significant difference in the mean values seen between males and females.

Similar to the findings of the present study, Ferrand & Bloom (1996) conducted a study in children in the age range of 3-10 years. Findings indicated that the mean F0 of the males decreased at around age 7-8 years. Additionally, maximum F0 range, and percentage of rising and falling shifts all showed decreases for the males starting at ages 7-8y not paralleled by decreases for the females. It appears that around age 7-8 males begin to restrict their intonational ranges, while females maintain similar patterns across age groups. In consistent with the present study, Weinberg & Bennet (1971) studied the mean speaking F0 of children in the age range of 6-7years. No significant difference between males and females were observed. Similar to the findings of the present study, Sorenson (1989) that there is a significant difference for speaking fundamental frequency across age and gender for children in the age range of 6- 10 years. Similarly, Wheat and Hudson (1988) has found that the speaking fundamental frequency of 6 year old males and females did not show any significant difference.

In contrast to the present study, the results of a study conducted by Wong et al (2011) in subjects in the age range of 4-18 years, has suggested that the parameters of intonation stimulability did not vary either with gender or age. It could be because in normal children the auditory and speech productions systems are intact and sufficiently robust to imitate the probe sentence well.

Syllabic rate

To study syllabic rate Kannada sentence “naanu sayankala manege hogthini” was used. From the results it was observed that all the parameters of syllabic rate like parameters like Average syllabic rate (SLrate), Average pause duration (SLpdur), Percentage speaking time (SLspk), Percentage pause time (SLpau) has shown a significant age group difference except for the parameter Average syllabic duration (SLsdur). The mean value for parameters like SLrate was observed to be increasing with age. Similar trend was noticed in only male and only female group. Percentage speaking time was also found to be increasing. A decrease in the mean value for the parameters SLpdur and SLpau was also observed with an increase in age. It was also observed that the age group difference was notice more in the comparison between 4-6y versus 8-10y.

The findings of the present study is in consolidation with the findings of Amster (1985) where he suggested that the syllabic rate in children with 5 years of age or older has shown a comparable developmental trend. Similar to the findings of the present study, various other studies have found that the rate tends to increase with age (Kelly, 1994; Kent & Forner, 1980; Kowal, O' Connel & Sabin, 1975; Walker, Archibald, Cherniak & Fish, 1992). Another study conducted by Kowal et al. (1975) did find an increase in speech rate in children in kindergarteners through high schoolers at 2-year intervals. As an explanation to the finding, the reduction in the mean values of segment duration with age could be the result of neuromuscular maturation and therefore measurements may be one way of characterizing a child's progression in development in achieving adult like speech motor control.

Another important finding of the present study is that age group differences where more significant when a younger age group (4-6y) was compared with a higher age group (8-10). Similar to the findings of the present study Pindzola, Jenkins, and Lokken (1989) has demonstrated that there were no significant differences in speaking rate across the age group 3-5 years. Amster and Starkweather (1985) found significant differences in rate between 2-year-olds and older preschoolers but nonsignificant differences among 3 to 5-year-olds. This suggests that developmental rate changes do not proceed on a yearly basis but rather increase sporadically at certain age intervals. According to Kowal et.al (1975) there is a significant increase in the rate of speech between 2 and 3 years but not again until the early school years.

Another finding of the present study is the decrease in the mean value for the parameters SLpdur and SLpau was also observed with an increase in age. The findings of the present study is supported by various there studies where they have suggested that reduction in the segmental duration with age in children (Kubaksha & Keating, 1981; Nittrouer, 1993; Robb & Saxman,1990 & Iverson, 2010. In consistent with the present study, Smith (1978) where the findings suggests that the duration of segments were longer in children when compared to adults in which reduction in duration was found in 4 year olds when compared to 2 year old children.

In consistent with the present study, Walker et al (1992) suggested that there is no gender difference in terms of speech rate in a study done in children in the age range of 3-5 years. In contrast to the present findings Dawson (1929) reported that speech rate of girls were faster when compared to boys until the age of twelve.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Speech is an important medium through which we humans communicate to exchange our ideas, thoughts and information. It is a unique, dynamic and complex motor activity which begins from birth and continues to develop till puberty. The attainment of adult speech motor control is dependent on maturation of the individual's nervous system. Speech motor control refers to the systems and strategies that control the production of speech. The articulatory movements for the production of speech are solely under neuromuscular control. The motor patterns of speech speculate the co-ordinated function of the Central Nervous System.

Preadolescent children exhibit speech motor control that is unlike that of adults, the use of adult standards or norms in the clinical evaluation of children's speech and oral motor control is incompatible. Children's ability to carry out various speech and non-speech motor tasks, and the variability in the execution of such tasks, forbids the use of adult-based standards with children. The normal speech characteristics during childhood have been studied by various researchers. There are some normative data established using subjective methods, but that does not address the entire childhood years.

The aim of the present study was to determine the normative data for speech motor characteristics in 4-10 year old typically developing Kannada speaking children and to compare the results across age and gender. A total of 90 native Kannada speaking (Mysore dialect) typically developing children in the age range 4 to 10 years were enrolled in the study. The participants were divided into 3 subgroups (4-6 years, 6-8 years and 8-10 years). Each subgroup consisted of 30 participants in which 15 were males and fifteen were females. Parameters like diadochokinetic (DDK) rate, second formant transitions (F2), voice and tremor parameters, intonation stimulability, and syllabic rates were assessed using The Motor Speech Profile (MSP) Model 5141 module. It is one of the module in CSL (4500, Kay PENTAX, NJ)

Statistical analysis was done using SPSS 17.0 to know the age and gender effect. The Kruskal Wallis test was done to see the overall effect of age. Those parameters which showed a significant difference was further taken up for pair wise comparison. Mann-Whitney U test was carried out to know the gender effect.

In the present study the mean values of DDK parameters like Average DDK Rate (DDKavr), Maximum Intensity of DDK Sample (DDKmxa), Average Intensity of DDK Sample (DDKava), Average Syllabic Intensity (DDKsla) were found to be increasing with age. The results have also indicated that there is a significant decrease in the mean value of Average DDK period (DDKavp) with increase in age. This could be because of the neural maturation that is taking place with age leading to better coordinated control over musculatures. Overall there was no significant gender effect seen across age groups. Differences in the mean values of the DDK parameters were less in 4-6 versus 6-8 age group comparison when compared to 6-8 versus 8-10yrs.

In second formant transition, it was noted that there was a reduction in F2 magnitude (F2magn) and F2 minimum (F2min) with the progression in age group.The F2 rate significantly increased with age. No gender difference was noticed across age group. The reduction in the F2 magnitude and increase in F2rate suggests an increased accuracy and control over the articulators with development. The results are consistent with the developmental processing involving gradual acquisition and fine tuning of speech motor patterns.

Voice and tremor parameters showed no significant effect of gender observed across age groups. With the progression in age, the mean value for parameters like Fundamental frequency (F0), Highest fundamental frequency (Fhi), Lowest fundamental frequency (Flo), Standard deviation of fundamental frequency (STD), Coefficient of variation of amplitude (vAm) were found to be decreasing, with a greater change noticed in males compared to females. The mean value of tremor parameters was found to be increasing with age. There were no much of difference seen between 4-6y and 6-8 years. But there was a greater difference noticed between 4-6y and 8-10 year groups. Crelin (1973) suggested that gender differences in laryngeal size and thyroid angle begin to appear by the third year which leads to acoustical changes in (reduction in F0) in children by 7 years. The increase in the mean values of perturbations measures could be due to maturational changes in the laryngeal system leading to variability and instability of vocal fold vibration as children reaches puberty. Thus the changes in the acoustic measures seen in the study correspond to the physiological changes underlying the speech production.

In intonation stimulability most of the parameters were seen to be significantly difference of intonation stimulability has shown a significant difference across age group. The mean value and SD for parameters like Running speech fundamental frequency (rF0), Highest fundamental frequency (rFhi), Amplitude variability (rvAm) was found to be decreasing with increase in age. Most of the frequency parameters were found to be decreasing with age in which greater changes were noticed between 6-10 years. No significant gender effect was noticed across age groups.

The finding of syllabic rate parameter has indicated that the mean value for syllabic rate and percentage speaking time (SLspk) increased with age and a similar trend was noticed in only males and only females group. Syllabic duration (SLdur) and percentage pause time (SLpau) was found to be decreasing with age. It was also observed that the age group difference was notice more in the comparison between 4-6y versus 8-10y. Overall there was no gender effect noticed across age group. The reason for the above results could be due to neuromuscular maturation and therefore measurements may be one way of characterizing a child's progression in development in achieving adult like speech motor control.

Normative score for speech motor skills is mentioned in the results.

Implications of the study

- The result of the current study serves as the normative for children in the age range of 4 to 10 years for several aspects of speech motor skills in Indian context.
- The normative values can be compared with that of disordered population for the purpose of management and to distinguish between changes taken place by clinical intervention versus normal maturational process.
- This study add on to the existing knowledge on the development of motor speech characteristics

Limitations of the study

- As sound treated rooms were not available in the schools where recording was carried out, the ambient noise levels could not be controlled adequately. This would have shown accurate measures for voice and tremor measurement.

Future directions

- Normative values can be established for adolescent group (11-18 years).
- The study can be replicated in other Indian languages as language specific norms can help in better assessment and management of individuals with motor speech disorders.
- More number of subjects would minimize the error in estimating normative.

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