TEMPORAL CHARACTERISTICS OF SPEECH IN CHILDREN WITH SPEECH SOUND DISORDER:

AN EXPLORATORY STUDY

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July 2020

CERTIFICATE

This is to certify that this Dissertation entitled is **"Temporal Characteristics of Speech in Children with Speech Sound Disorder: An Exploratory Study"** a bonafide work submitted in partial fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration Number: 18SLP035). 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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This is to certify that this Dissertation entitled is **"Temporal Characteristics of Speech in Children with Speech Sound Disorder: An Exploratory Study"** has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma (or) Degree.

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This is to certify that this Dissertation entitled is **"Temporal Characteristics of Speech in Children with Speech Sound Disorder: An Exploratory Study"** is the result of my study under the guidance of Dr. N Sreedevi, Professor & Head, Department of POCD, 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.

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July, 2020

Registration No.
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This is work is dedicated to

My dear parents,

to my Guide and

Dear friends

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TABLE OF CONTENTS

List of Tables

LIST OF FIGURES

CHAPTER I

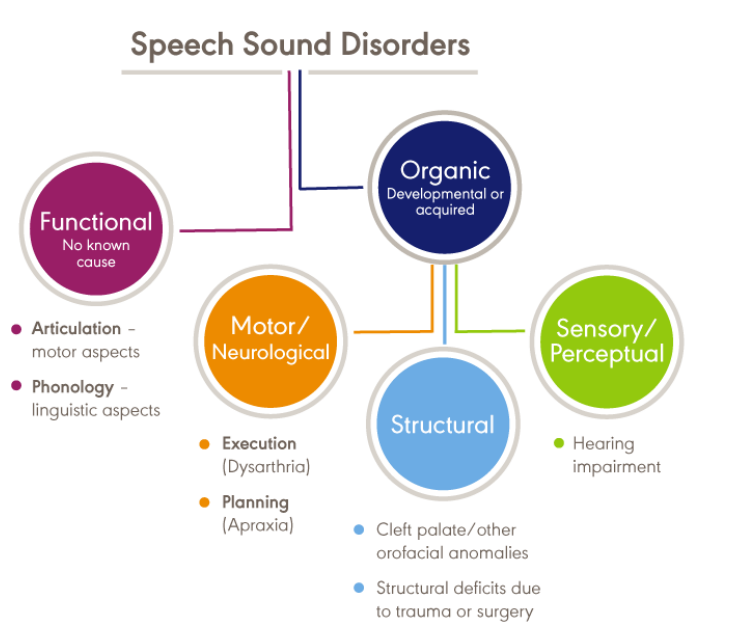
Introduction

Speech Sound Disorder (SSD) is an umbrella term that refers to any problem or combination of a problem with perception, motor development, or phonological representation of speech and speech fragments, including phonotactic rules regulating acceptable speech sound sequences in a language. Speech sound disorders can be organic or functional in nature.

- **Organic speech sound disorders** are the product of underlying motor / neurological, physiological, or sensory/perceptual causes.
- **Functional speech sound disorders** are idiopathic.

Figure1

Classification of Speech Sound Disorder



Note. (Source: https://www.asha.org/practice-portal/)

SSD is a communication disorder characterized by difficulty in articulating and producing correct sounds in children without any neurological or physical deficits. For accurate speech production, multiple domains such as perceptual, cognitive, linguistic, and motoric patterns are required for children during the development of the speech sound system. Children with SSD are stated that they have difficulties in segmenting new words into phoneme units in order to make the correct association between the sounds and the motor patterns necessary to articulate the new words (Munson et al, 2005).

Any difficulty with phonological representation, motor production, and/or perception of speech sounds and speech segments affecting speech intelligibility refers to SSD. It is mainly caused due to motor speech disorder (e.g., apraxia and dysarthria), structural based disorders (e.g., cleft lip and palate & other craniofacial anomalies) and sensory disorders (e.g., hearing impairment).

Leonard (1992) described children with phonological disorder or speech sound disorder (SSD) as those with severe difficulties in learning the sound system of their language, with otherwise normal hearing, age-appropriate non-verbal intelligence, and no neurological impairment. Speech errors in children with SSD are usually similar to those of younger children who normally develop. Children with SSD are presumed to have been delayed in phonological systems, thus demonstrating the ability to "catch up" with the same age group with the provision of appropriate speech sound intervention (Edwards et al., 1983).

Phonetic refers to speech sound production. It is the mechanism by which sounds, syllables, and words are created when tongue, mouth, teeth, lips, and palate change the flow of air coming from the vocal folds. If a person cannot produce or distort age-expected sound/s, he or she draws attention away from the speaker's message. Phonetic disorders are motor errors that can occur in people of any age; however, they are most common in children whose articulators have not developed properly. Phonetics is the motor act of producing words and consonants so that we have an inventory of all the sounds we need to express our languages. The phonetic disorder is a weakness in the capacity of the articulator to create a sound in isolation, syllable, word, paragraph, or conversational expression that is not compatible with the chronological period.

Errors in children with SSD are usually classified into four types (Van Riper & Irwin, 1958). These are

- Substitutions: One or more of the sounds are replaced by another.
- Omissions: Certain sounds are not produced in full syllables or classes of sounds may be deleted.
- Additions: An additional sound or sound is applied to the intended word.
- Distortions: Sounds are subtly modified so that the intended sound can be heard but it sounds "wrong" or may not sound like any sound in the language.

Children with SSD use less number of diverse consonant and vowel types in the production of word forms relative to typical productions. The child's word forms are primarily using the earlier developing phonemes. It is stated that with increasing age and linguistic experience, the motor control governing speech improves (Kent & Read, 2002; and Nittrouer, 1993). Age-related reductions in mean word and segment durations and period variation are acoustically inferred as changes in motor function. (Chermak & Schneiderman, 1986; Di Simoni, 1974; Kent, 1976; Kent & Forner, 1980; Smith, et al., 1996)

Weismer and Elbert (1982) argued that children with /s/ misarticulation had a higher temporal variation than children of the same age with normal /s/ articulation. Compared to typically developing children (TDCs), the high acoustic variation exhibited by children with SSD suggests impaired motor coordination in speech. Advances in motor control as well as exposure to the language spoken in their environment contribute to a child's acquisition of speech as implied by the Biological Theory of Phonological Development (Kent, 1992). Thus, when compared acoustically to the age of typically developing children (TDC), maturation constraints would be shown as longer and more variable speech segment durations in children with SSD.

Macrae et al. (2010) reported that children with SSD had a longer duration than same-aged and gender-matched children with No Speech-Sound Disorder (NSSD). Children with SSD had the longer word, consonant, and vowel durations than children with NSSD. Words and vowels were produced with slightly longer durations, and consonant durations were considered to be important due to the developmental differences in the organization of vowels and consonants.

1.1 Need for the Study

Within the last few decades, Speech-Language Pathologists have become increasingly aware of the need for objective descriptions of disordered speech production. Such descriptions are mandatory if ongoing evaluations and interventions need to be based on scientific rather than unfounded principles. There has been ongoing research in the area of acoustic analysis of speech development in children for its non-invasive nature. There are numerous research reports on the acoustic characteristics of both normal and disordered speech of children. E.g., Speech of children with hearing impairment, cleft lip, and palate, dysarthria, etc. Nevertheless, acoustic analysis of speech in children with speech-sound disorders is minimal, although there is evidence of a temporal correlation between pre-planned motor activity and the presence of phonological disturbances (Tingley & Allen, 1975). Duration studies have important consequences for the development of speech timing regulation as adult speech activity is under fine control. Due to the significance of timing variables in every motor ability, temporal speech measures are useful and provide a responsive metric for evaluating the neuromuscular maturation of the speech system. The functionally misarticulated speech is presently addressed as SSD due to unknown origin may be a manifestation of developmentally delayed or deficient motor behavior. A couple of earlier researchers also have reported the same (Bruner, 1973; Kent, 1976 and Weismer & Elbert, 1982). One of the possible explanations for the differences is that children with SSD are less precise than the normally articulating children in reproducing segment durations because of their somewhat poor speech motor control. Hence the present study is a preliminary attempt to look into the temporal characteristics of vowels, consonants, and word duration among children with SSD and typically developing children in an Indian context.

1.2 Aim of the Study

To analyze and compare the temporal characteristics of the speech of native Kannada speaking children with speech sound disorder (SSD) and age and gender-matched Typically Developing Children (TDC).

1.3 Objectives

The main objectives of the study were

1) To obtain the word duration in native Kannada speaking children with Speech Sound Disorder (SSD) and Typically Developing Children (TDC) in the age range of 4- 8 years and establish the difference in word duration between the groups.
2) To obtain the consonant duration in native Kannada speaking children with SSD and TDC in the age range of 4-8 years and establish the difference in consonant duration between the groups.
3) To obtain the vowel duration in native Kannada speaking children with SSD and TDC in the age range of 4-8 years and establish the difference in vowel duration between the groups.

1.4 Hypothesis

The study assumed the following null hypotheses:

1) There is no significant difference in word duration between children with SSD and TDC in native Kannada speakers in the age range of 4-8 years.
2) There is no significant difference in consonant duration between children with SSD and TDC in native Kannada speakers in the age range of 4-8 years.
3) There is no significant difference in vowel duration between children with SSD and TDC in native Kannada speakers in the age range of 4-8 years.

CHAPTER II

Review of Literature

Speech is the communication of ideas and thoughts by vocal sounds expressed, or the ability to convey ideas and thoughts in this way. According to DeVito (1986) communication is defined as the "method or act of transmitting a message from a transmitter to a receiver, through a channel, and with noise interference". In the process of communication, the individual relates and exchanges the experiences, ideas, knowledge, and feelings with others using symbols and transmits those symbols either through auditory or visual modes. For communication, human beings use several symbolic systems, e.g: speech, sign language, writing, singing, Morse code, etc. Speech is one of the most commonly used and efficient modes of communication and it is the verbal representation of one's cognitive process and feeling. Clarity of speech is important for social interaction, for educational and occupational functioning, for self-confidence, self-image, and sense of self-efficacy. Speech impairment has a negative effect on all these areas. Diagnosis assigned to individuals who have difficulties in the productive speech which interferes with communication, and produces impairment in functioning, and distress. This means there's inefficient communication in the areas of the brain responsible for speech production.

2.1 Speech Sound Disorder

According to ASHA, 2004, SSD is a wider term that refers to "a combination of difficulty in speech perception, speech motor development, and phonological representation of speech sounds and speech segments, including phonotactic language rules and prosody that have an effect on speech intelligibility" The impact may be either on the formation of speech sounds resulting in articulation disorders or on the functioning of speech sounds resulting in phonological disorder. Articulation disorders are generally associated with structural (cleft lip & palate) and motor-based difficulties (apraxia) whereas Phonological disorders are the impairments in the phonological representation of speech sounds and speech segments within the context of spoken language. In SSD, phonemes, or the basic units of speech, may be added, omitted, distorted or changed, or substituted in a manner in a way that makes it impossible for the speaker to understand (ASHA, 2014).

2.1.1. Phonetic vs. Phonological Disorders

Speech Sound Disorder includes both phonetic (Articulation) and phonological disorders. An articulation disorder refers to problems with the aspects of speech motor production or a failure to produce certain speech sounds (Elbert & Gierut, 1986). This type of condition has been defined as phonetic; that is the difficulty lies in how sounds are produced (Dinnsen,1984) while a phonological disorder affects production and/or mental representation of the target language speech sounds by a speaker. This type of disorder has been defined as phonemic, as the difficulties can involve how sounds are used to signal the meaning difference between words (Dinnsen, 1984). Table: 2.1 shows Differences between articulation and phonological disorders are as follows

Table 2.1

Difference between Phonetic and Phonological Disorders

Phonetic Disorders	**Phonological Disorders**
Phonetic errors	Phonemic errors
Problems in speech production	Problems in the language-specific function of phonemes
Difficulties with speech sound forms	Difficulties with phoneme function
Disturbances in relatively peripheral motor processes that result in speech errors	Disturbances are more central, concerning the phonological level of the organization of the language system.
Speech sound production difficulties do not typically impact other areas of language development such as morphology, syntax, or semantics.	Phoneme difficulties may impact other language areas such as morphology, syntax, or semantics.

2.1.2 Incidence and Prevalence

The prevalence rate of speech sound disorders is high (approx. 7.5%-18.6%) compared to other speech disorders in children (Cavalheiro et al., 2012; Devadiga et al., 2014; Jayashree et al., 2015; Karbasi et al., 2010; McLeod et al., 2009, Shriberg et al., 1994). SSD is a significant communication problem in school-aged children (Pena-Brooks et al., 2017). A survey by ASHA (2006) found 91% of SLPs working in public schools serving children with SSD. Mullen and Schooling (2010) reported 56% of school-based SLPs serving children with SSD. Literature found that children with SSD were at risk for either short-term or long-term difficulties in a variety of domains, such as academics (writing and reading), social and emotional subjects, which ultimately impacted employment opportunities in adulthood. (Felsenfeld et al., 1994; Raitano et al., 2004). Gillon (2017) reports literacy difficulties and phonological deficiencies are strongly correlated. Children with severe phonological disorders have frequently experienced problems with phonological awareness. (Gillon, 2017); phonological representation (Nathan et al., 2004; Stackhouse, 1997); reading (Bird et al., 1995); and spelling (Clarke-Klein et al., 1995). Also, incorrect production of speech sounds leads to speech unintelligibility posing a robust negative effect on social and emotional aspects as well. Findings of retrospective studies on co-occurring difficulties of SSD noted adults with the phonological disorder in childhood having global challenges in retrieving, manipulating, and comprehending the linguistic information (Felsenfeld et al., 1992; Felsenfeld et al., 1995; Lewis et al., 1989, Lewis et al., 1992). Felsenfeld et al. (1994) found 70% of the adults with a history of phonological problems have not received a college degree and have often kept an unskilled job. These reports necessitate early identification and management of speech sound disorders.

2.2 Speech Production: Developmental aspects

Speech can be characterized as the development of voice sounds for communication through the process of respiration, phonation, resonation, and articulation. This definition connects several important concepts, including sound (the acoustic speech signal), communication (the speech purpose), and underlying physiology (the biological mechanism involved in speech production. Speech is exclusively important for a variety of reasons. From the neurosciences, speech is a remarkable motor skill. Normal conversational speech can be produced at rates of up to six to nine syllables

(20 to 30 individual speech sounds) per second. No other discrete human motor performance rivals that rate. Speaking also has more motor fibers than any other human mechanical activity and there is growing evidence that the motor fibers are uniquely equipped for the requirements of speech. Kent and Hustad, (2009) studied the speech development and production. They had given four stages of development in speech production. These are

2.2.1 Speech Development in Infants (0 to 12 months)

From birth to 2 months, infants primarily produce vocalizations that consist of crying and vegetative types of sounds with little or no articulation. Between 2 and 6 months, infants produce cooing sounds and laughter and begin to make some simple articulatory movements during vocalization. Vowel and consonant sounds may be produced in vocal play contexts in which there is an elevation in control of phonation. Between 7 and 12 months, infants begin canonical babbling and variegated babbling. At approximately one year of age, plus or minus two months, most children utter their first words.

2.2.2 Speech Development in Toddlers (12 to 24 months)

Although children with typical development produce words during this period, they also continue to engage in babbling behavior. Indeed, the phonetic inventory of toddlers stays relatively consistent until approximately 18 months of age. At this time, toddlers produce nearly two or three times more consonants than vowels and have around six consonants in their verbal repertoire (usually stops, nasals, and glides). Between 18 and 24 months, phonetic inventory size increases to approximately 10–20 consonants, and the inventory of consonants used in the initial syllable position increases more rapidly than the inventory for the syllable-final position. By 2 years, children have an average Percentage of Consonant Correct (PCC) of approximately 70%. Although children at this age have a reduced repertoire of sounds relative to the adult, they seem to favor words that are within their phonetic repertoire and are on the path to achieving adult-like mastery.

2.2.3 Speech Development in Preschoolers (2 to 6 years)

Children make a vital improvement in their ability to produce different speech sounds that are adult-like production between the ages of 2 and 6 years. By approximately 5 or 6 years of age, most of the children achieve most of the speech sounds of the English language in their verbal repertoire, though they probably have not 'mastered' all sounds. Researchers found, children between 3 and 11 years of age; develop 92.5 % of articulation 'normally,' such that any developmental speech sound errors resolve spontaneously without the need for interventions. Also, children between the ages of approximately 4 and 5 years produce continuous speech that is highly intelligible. It is during this period of development, many childhood disorders of communication can be identified, like disorders of articulation, language, and developmental stuttering.

2.2.4 Speech Development in Older Children (above 6 years)

At this developmental period, children make qualitative refinements in their phonetic development. By the age of approximately 6 years, children with typical development have all phonemes in the English language within their verbal repertoire.

They can produce all consonant singletons precisely in more than 51% of occurrences. By approximately 8 years, Children reach 90% ‘mastery’ of all consonant singletons. Production of consonant clusters continues to undergo refinements toward adults like production levels through 9 years of age. Gradually, children attain adult-like phonetic abilities before the age of 10 years. But the continuing improvement/ refinement of speech motor control is evident until the age of approximately 16 years.

2.2.5 Development of Speech Motor Synergies

The development of articulatory synergies in infants is distinct. Speech production in infants is thought to be restricted to sounds primarily which are supported by the mandible (Davis et al., 1995; Green et al., 2000 and MacNeilage et al., 1990). Early mandibular movements (∼1 year or less) are ballistic and restricted to opening and closing movement due to the limited fine force control required for varied jaw heights (Kent, 1992; Locke, 1983 and Green et al., 2000). In the first year, vowel productions are related to low, non-front, and non-rounded vowels; implying that the tongue hardly raises from the jaw, and there is limited interaction of facial muscle (lip) (i.e., synergy) with the jaw (Buhr, 1980; Diepstra et al., 2017; Giulivi et al., 2011; Kent, 1992 and Otomo et al., 1992).

The sequences of sound that do not require complex coordination and timing within/between articulatory gestures are easier to produce and the first to emerge (Green et al., 2000 and Green et al., 2010). For example, young children are unable to coordinate laryngeal voicing gestures with supra-laryngeal articulation and hence master voiced consonants and syllables earlier than voiceless ones (Kewley-Port et al., 1974 and

Grigos et al., 2005). The synergistic interaction between the laryngeal and supra-laryngeal structures underlying voicing contrasts is achieved by around 2 years of age (~20–23 months; Grigos et al., 2005), and follows the maturation of the movements of the jaw (around 12–15 months of age; Green et al., 2002) and/or jaw stabilization (Yu et al., 2014).

In children, up to and around 2 years of age, there is limited fine motor control of jaw height (or jaw grading) and weak jaw-lip synergies during bilabial production, but relatively stronger inter-lip spatial and temporal coupling (Green et al., 2000, 2002; Green et al., 2010 and Nip et al., 2009). A possible outcome of these interactions is that their vowel productions are limited to that of extremes (high or low; /i/, /u/, /o/, and /ɑ/), and lip rounding/retraction is only present when the jaw is in a high position (Kent, 1992 and Wellman et al., 1931). As speech-related jaw-lip synergies are emerging, it is not surprising that children's ability to execute lip rounding and retraction is possible when degrees of freedom can be reduced (i.e., when the jaw is held in a high position). Observation of such a reduction in degrees of freedom in emerging synergies has been observed in other non-speech systems (Bernstein, 1996).

Interestingly, although the relatively strong inter-lip coordination pattern found in 2-year-olds is facilitative for bilabial productions, it needs to further differentiate to gain independent control of the functionally linked upper and lower lips before the emergence of labio-dental fricatives (/f/ and /v/; Green et al., 2000;). This process is observed to occur between the ages of 2 and 3 years (Green et al., 2000 and Stoel-Gammon, 1985). Green et al. (2000, 2002) suggest that upper and lower lip movements become adult-like with increasing contribution of the lower-lip toward bilabial closure between the ages of

2 and 6 years. Further control over jaw height (with the addition of /ɛ/ and /ɔ/) and lingual independence from the jaw is developed around 3 years of age (Kent, 1992). The latter is evident from the production of reliable lingual gliding movements (diphthongs: /aʊ/, /ɔɪ/, and /aɪ) in the anterior-posterior dimension (Donegan, 2013; Kent, 1992; Otomo et al., 1992 and Wellman et al.,1931). Control of this dimension also coincides with the emergence of coronal consonants (e.g., /t/ and /d/; Smit et al., 1990; Goldman et al., 2000). By 4 years of age, all front and back vowels are within the spoken repertoire of children, suggesting a greater degree of control over jaw height and improved tongue-jaw synergies (Kent, 1992). Intriguingly, front vowels, and lingual coronal consonants emerge relatively late (Wellman et al., 1931; Kent, 1992; Otomo and Stoel-Gammon, 1992). This is possibly due to the fine adjustments required by the tongue tip and blade to adapt to mandibular angles. Since velar consonants and back vowels are produced by the tongue dorsum, they are closer to the origin of rotational movement (i.e., condylar axis) and are less affected than the front vowels and coronal consonants (Kent, 1992 and Mooshammer et al., 2007). With maturation and experience, finer control over tongue musculature develops, and children begin to acquire rhotacized (retroflexed or bunched tongue) vowels (/ɝ/ and /ɚ/) and tense/lax contrasts (Kent, 1992).

The later development of refined tongue movements is not surprising since the tongue is considered a hydrostatic organ with distinct functional segments (e.g., tongue tip, tongue body; Green et al., 2003; Noiray et al., 2013). Gaining motor control and coordinating the tongue with neighboring articulatory gestures is difficult (Kent, 1992; Nittrouer, 1993 and Smyth, 1992). Cheng et al. (2007) study demonstrated a lower degree and more variable tongue tip to jaw temporal coupling in 6- to 7-year-old children relative to adults. This contrasts with the earlier developing lip-jaw synergy reported by Green et al. (2000), wherein by 6 years of age, children's temporal coupling of lip and jaw was similar to adults. The coordination of the tongue's subcomponents follows different maturation patterns. By 4–5 years, synergies that use the back of the tongue to assist the tongue tip during alveolar productions are adult-like (Noiray et al., 2013), while synergies relating to tongue tip release and tongue body backing are not fully mature (Nittrouer, 1993). The extent and variability of lingual vowel-on-consonant co-articulation between 6 and 9 years of age are greater than in adults; implying that children are still refining their tuning of articulatory gestures (Cheng et al., 2007; Nittrouer, 1993; Nittrouer et al., 1996, 2005 and Zharkova et al., 2011).

These findings suggest that articulatory synergies have different schedules of development: lip-jaw related synergies develop earlier than tongue-jaw or within tongue-related synergies (Cheng et al., 2007; Terband et al., 2009). Most of this work has been done on intra-gestural coordination (i.e., between individual articulators within a gesture), but it is clear that both the development of intra- and inter-gestural synergies are non-uniform and protracted (Smith et al., 2004 and Whiteside et al., 2003). Variability of intra-gestural synergies (e.g., upper- and lower-lip or lower lip–jaw) in 4- and 7-year-olds are greater than with adults but decreases with age until it plateaus between 7 and 12 years (Smith et al., 2004). Adult-like patterns are reached at around 14 years, and likely continuously refine and stabilize even up to the age of 30 years (Schötz et al., 2013 and Smith et al., 2004). Overall, these findings suggest that the development of speech motor control is hierarchical, sequential, non-uniform, and protracted.

2.3 Speech Sound System

Speech mechanism involved the structural synchronization of continuously shifting of the articulators producing the sound of speech: tongue, lips, jaw, vocal tract, vocal cords, and respiration. The acoustic signal generated during speech production, when the vocal organs move, resulting in the patterns of the air molecules in the air stream. The speech waveform is the product of the interaction of one or more sources with the vocal tract filter system (Fant, 1960). Speech sounds are classified into vowels and consonants. Vowels are speech sounds produced by voiced excitation of the open vocal tract. The energy produced through the oral or nasal cavity can be radiated without audible friction or stoppage. Vowels can be classified based on tongue height, tongue advancement, degree of muscular effort, rounding of lips, duration, the position of the soft palate, and tone. Consonants are the speech sound that is articulated with a complete or partial closure of the vocal tract. Consonants can be classified based on place, manner, and voicing features.

2.3.1 Vowels

Tosi (1979) defined vowel "as a continuant sound' (it can be produced in isolation without changing the position of articulators), voiced (using the glottis as the primary sound of source) with no friction (noise) of air against the vocal tract". In other words, the vowel "is a speech sound resulting from the unrestricted passage of the laryngeally modulated air stream, radiated through the mouth or nasal cavity without audible friction or stoppage" (Nicolosi et al 1978). Vowels are described in terms of

1) Relative position of the constriction of tongue in the oral cavity (front, central and back)
2) Relative height of the tongue in the oral cavity (high, mid and low)
3) Relative shape of the lips (spread, rounded and unrounded)
4) Position of the soft palate (nasal and oral)
5) Phonemic length of the vowel (short and long)
6) Tenseness of the articulators (lax and tense)

2.3.2 Consonants

Consonants are defined as the speech sounds produced with or without vocal fold vibration, by certain successive contractions of the articulatory muscles which modify, interrupt, or obstruct the expired air stream so that its pressure is raised and facilitates the production of burst or friction, etc., (Nicolosi et al., 1978).

Consonants are described based on

1) Manner of articulation (stop, fricative, affricate, glide, trill.... etc.)
2) Place of articulation (bilabial, dental, alveolar, retroflex, velar... etc.)
3) Role of vocal folds (voiced and voiceless)
4) Position of the soft palate (nasal and oral)

2.3.3 Phonetics of Kannada

Kannada known in English as Kanarese; is a south Dravidian language spoken in and around Karnataka. Kannada similar to other Dravidian languages is found to comprise several phonological contrasts absent in the phonologies of other languages (Schiffman, 1979). Majority of these contrasts being the existence of retroflex consonants and the contrasts between the short and long vowels. Kannada is also found to exhibit consonantal contrasts borrowed from Sanskrit and other languages especially the aspirated series and vowels such as and [o].

Classification of vowels in Kannada: The basic Kannada vowel system is believed to comprise of five long and five short vowels. Diphthongs that are present in the standard Kannada phonetic system are [ai] and [au].

Classification of vowels according to tongue height and advancement in Kannada language (Schiffman, 1979)

- High vowels: the high vowels of Kannada are [i] and [u] and long vowels are [i:] and [u:] respectively. [i] Is a high front unrounded vowel that occurs in all positions of initial, medial, and final. It is reported to be a more lax vowel in all the positions and even more lax before a geminate cluster. [u] is a high back rounded vowel which researchers report as being in between low-high in the initial and medial positions but high in the final positions (Schiffman, 1979).
- Mid vowels: the mid vowels in Kannada are the front vowels [e], [e:] and the back vowels [o] and [o:]
- Low vowels: the low vowels in Kannada are the central vowels [a] and [a:]

Classification of consonants in Kannada

Kannada is reported to be a repository of Dravidian consonants with a superimposed system of aspirated consonants and certain sibilants borrowed from Indo Aryan, Urdu, and English languages. The consonantal classification as provided by (Schiffman, 1979) according to the place and manner features is as follows

- Velar consonants: are [k, kh, g, gh and ŋ). The first four consonants belong to the class of voiced and voiceless stops and the fifth belongs to the velar nasal respectively.
- Palatal consonants: [ʧ, ʤ, ʧh, ʤh, and ñ]. The first four consonants belong to the class of voiced and voiceless affricates and the fifth belonging to the class of palatal nasal.
- Retroflex consonants are the [d, t, ŋ) the first two being voiceless and voiced retroflex stops, and the next being retroflex nasal sound.
- Dental consonants: these are [n, t̲, d̲). The first is a dental nasal sound and the next two are voiceless and voiced dental stops respectively.
- Labial consonants: these are [p, b, m]. The first two are voiceless and voiced bilabial stops and the next is a bilabial nasal sound.
- Other consonants: Glides: the Kannada glides are the [j] and [w]. Sibilants and fricatives: [s, ʃ]. Lateral and glottal fricatives: [l. r, h].

Basanti Devi (1996) report on the developmental milestones of language acquisition in Hindi and Kannada revealed that the cardinal vowels [i], [e], [a], [u], and [o] first appeared by 6-12 months of age in Kannada followed by the vowels [i], [i:], [u], [u:], [e], [e:], [a], [a:] and [o], [o:] seen in the toddlers aged between 12-18 months of age. Diphthongs [ou] and [ai] were found to be absent in all the participants. Under the place feature of consonants, velars, palatals, retroflex, dental, and labials were reported to be present in all the participants, and under the manner feature, stops, nasals glides, sibilants and fricatives were found to be present. Laterals were reported to be seen only in the oldest participant of the age group.

2.4 Acoustic Studies on Temporal Parameters of Speech

Speech is a form of communication in which the transmission of information takes place through speech waves which are in the form of acoustic energy. The speech waveforms are the result of one or more sources with the vocal tract filter system (Fant, 1960). Acoustic characteristics of speech sounds will give information about the articulatory nature of the sound and also how these sounds are perceived. Acoustic analysis of speech sounds provide information about the source characteristics like fundamental frequency, intensity, and filter characteristics like formant frequencies, formant bandwidths, and the temporal characteristics like vowel duration, consonant duration apart from the spectral characteristics.

For the past years, several acoustic and physiological studies have been conducted concerning the development of speech motor control in young children. Reasons for investigating this phenomenon range from attempting to gain a better understanding of normal children's progress towards adult-lik//fc e speech production abilities and for establishing a more adequate basis for evaluating speech motor disorders in both children and adults (Kent et al.,1980; Robb et al., 1989; Sharkey et al., 1985; Smith et al., 1986, 1987). Regardless of the specific purposes that have prompted these studies, two measures that have frequently been discussed when comparing speech motor skills among different age groups or between normal and disordered speakers are a) the duration of various units of speech and b) the variability of inter and intrasubject duration measures. One reason for considering these parameters is that at least for children and disordered adult speakers they are thought to be global indicators of neuro motoric integrity for speech production. Such studies of the speech of both normal and disordered children and adults have commonly observed the tendencies toward decreasing duration decreasing inter and intrasubject variability for normal as compared to disordered speakers. Acoustic analyses are appropriate to test a certain hypothesis about developmental changes in anatomy, m00otor control, and phonological functions. Acoustic analysis of speech of children is safe and convenient compared to EMG, X-ray, etc.

In Indian languages, there are several r0eports on temporal parameters of speech. Sreedevi (2000) studied age influences on vowel duration in Kannada and reported that in all the three age groups studied (6-9 years; 14-15 years and 20 - 30 years); females had longer vowel duration than males and with an increase in age, vowel duration reduced. The developmental variation trends were stronger in short than long vowels. Also, the long vowels were twice as long as the short vowels.

Jenson et al. (1972) investigated the vowel duration of Malayalam vowels which contrast phonemically in length. They also reported that on average, duration of long vowels was approximately twice that of their short vowel counterparts and they inferred that the linguistic distinction between short and long vowels may reside in the single parameter of duration. Also, the vowel duration of short vowels increases directly in proportion to the degree of mouth opening, with the ex0ception of /o/ which showed the longest duration.

A more elaborate study in Malayalam by Sasidharan (1995), reported that (a) there was significantly greater vowel duration in females than males in all three test positions- initial, medial and final positions, (b) in case of long vowels, the segmental durations were greater when the test vowel was in the word-initial position, whereas, in case of short vowels, the duration was longest in word-final positions and shortest in the word medial position; (c) in long vowels, the segmental durations were longest among the low vowels and shortest in case of high and mid vowels. In short vowels, segmental durations were longest among mid vowels; (d) vowel duration was found to be longest in case of central vowels and shortest in case of back vowels; (e) the rounded vowels had shorter vowel duration compared to unrounded vowels; and (f) the duration of long tense vowels were approximately twice that of short/ lax vowels.

2.4.1 Temporal Studies on Speech Sound Disorder

Macrae et al. (2010) studied acoustic analysis of word and segment duration in children with speech sound disorder. They stated that children with speech sound disorder (SSD) had longer durations than same-aged and gender-matched children with no speech sound disorder (NSSD). Children with SSD produced longer words, consonant, and vowel durations than children with NSSD. Words and vowels were produced with significantly longer durations, and consonant durations approached significance due to developmental differences in the organization of vowels and consonants.

Weismer et al. (1982) studied on temporal characteristics of functionally misarticulated /s/ in 4 to 6-year-old children. They found that children with /s/ misarticulation had greater temporal variability than children with normal /s/ articulation.

Catts et al. (1983) studied on speech timing of phonologically disordered children. They found that phonologically disordered children failed to differentiate Voice Onset Time (VOT) in word-initial voiced and voiceless stops and they produced much longer VOTs for voiceless stops than normal children. In the word-final voicing contrast, the phonologically disordered children evidenced longer consonant closure durations and less voicing during consonant closure than normal children. This result indicated that significantly more voicing errors in the initial and final stops of phonologically disordered children.

Collins et al. (1983) studied on spectrographic analysis of vowel and word duration in apraxia of speech. They stated that apraxic and normal groups showed reduced vowel duration as word increased in length. The apraxic speakers had significantly longer words and vowel duration than normal speakers.

McNeil et al. (1996) studied on effects of length and linguistic complexity on temporal acoustic measures in apraxia of speech. They found that apraxic speakers exhibited significantly longer vowels and between word-segment duration than normal speakers and also apraxic speakers consistently produced longer vowels and between word-segment durations in sentences than in word contexts.

Freeman et al. (1978) studied temporal coordination of phonation and articulation in a case of verbal apraxia. Results demonstrated that the VOTs of the apraxic speaker differed markedly from normal subjects. The apraxic productions did not include voicing lead for voiced stops. Lag times for voiced stops were longer than normal, while those for voiceless stops were shorter than normal, yielding a compression of the two categories and a marked overlap.

With the knowledge of the above-mentioned review of literature, it is noted the temporal measures have been studied in typically developing children in the Indian context. Since there is a lack of research in the clinical population, the present study aimed to study the temporal characteristics in the clinical population focusing on Speech Sound Disorder.

CHAPTER III

Method

The study aims to analyze and compare the temporal characteristics of the speech of native Kannada speaking children with speech sound disorder (SSD) and age and gender-matched typically developing children (TDC) and to make further statistical comparisons across the groups.

3.1 Participants

A total of sixteen (16) participants in the age range of 4 to 8 years were included for the present study. The participants were divided into two groups (Group I and Group II).

The Group I (Experimental group) consisted of 8 children with SSD (Phonetic type) diagnosed by a Speech-language pathologist as the experimental group in the age range of 4 to 8 years. Children with co-morbid conditions such as stuttering, central auditory processing disorder, and intellectual disabilities were excluded.

Group II (Control group) consisted of 8 typically developing children, age, and gender-matched with the experimental group as the control group in the age range of 4 to 8 years. The participants were screened for any disability using the WHO 10-disability screen questionnaire and were recruited from regular nursery and primary schools in Mysore.

Inclusion Criteria for Group I

1. Native Kannada Speaker.

2. Participants with a clinical diagnosis of Speech Sound Disorder (Phonetic Type with substitution errors only) based on the Kannada Diagnostic Photo Articulation Test (Deepa &Savithri, 2010).
3. Participant's production of target words should match the syllabic structure of the correct production of the words.
4. No structural or functional deficits on the oro-motor examination.
5. No associated audiological, visual, cognitive, psychological, or any other neurological problems.

Inclusion criteria for Group II

1. Native Kannada speaker.
2. Individuals with no history of any speech, language, hearing, or any cognitive/ neurological disorders.
3. No structural or functional deficits on the oro-motor examination.
4. Age and gender-matched with Group I participants.

3.2 Stimuli

The stimuli include a total of 13 words with 5 words for vowel measures and 8 words for consonant sound measures. Five vowels, /a/, /i/, /u/, /e/, /o/ and eight unaspirated stop consonants including both voiced and unvoiced were considered as target phonemes. Target words were selected from KDPAT (Deepa et al. 2010) which were picturable, unambiguous, and within children's vocabulary. The vowel duration was measured in the initial position and the consonant duration was measured in the medial position of the target words. Table 3.1 shows Kannada words containing phonemes in the present study.

Table: 3.1

Kannada words containing phonemes

S. No	Vowel Measures (Initial Position)	Consonant Measures (Medial Position)	
1	/adʒdʒI/ - /a/	/bekku/	- k-
2	/ili/ - /i/	/mu:gu/	- g-
3	/uŋgura/ - /u/	/tʃiṭṭɛ/	-ṭ-
4	/ele/ - /e/	/kannaḍəka/	-ḍ-
5	/onṭe/ - /o/	/ko:t̪i/	-t̪-
6		/kud̪ure/	-d̪-
7		/kappe/	-p-
8		/kabbu/	-b-

Note: In RP it was stated that consonant duration will be measured in both initial and medial positions of the target words. But later it was decided to measure only in medial position of the word as consonant duration is less likely to be measured in the initial position. Also the aspirated counter parts of the stop consonants were not considered. Hence only 8 unaspirated stop consonants of Kannada were included for stimulus preparation instead of 16 as mentioned in Research Proposal.

3.3 Procedure

Informed consent was obtained from all the parents/caregivers of the participants or school administrators before the recording. Participants were seated comfortably in a relatively quiet room with minimal background noise and were recorded individually. The picture stimuli were presented on a laptop computer screen. The participants were instructed to name each of the 13 target words for three trials in random order. The averages of the three trials were taken into consideration. Those children who were unable to name the picture shown, they were asked to repeat after the clinician. Participants were encouraged to name the target picture and appropriate verbal reinforcements were given for a correct response. The testing was carried out before the speech therapy intervention initiated for children with SSD (Group I).

Instrumentation

The Olympus multi-track linear PCM recorder (Model No: LS 100) was used for recording the samples. The mouth to microphone distance was maintained at 10-15 centimeters during the recording.

3.4 Data Analysis

The data were transferred to the personal computer for analysis. The acoustic analysis of the collected sample was carried out using the PRAAT software with 44.1 kHz sampling frequency (Boersma & Weenink, 2019) Version 6.1.01. The three recorded samples were analyzed and the average of each stimulus was taken and was further analyzed. Various acoustic parameters that were considered in the study are:

1) Word Duration

2) Consonant Duration

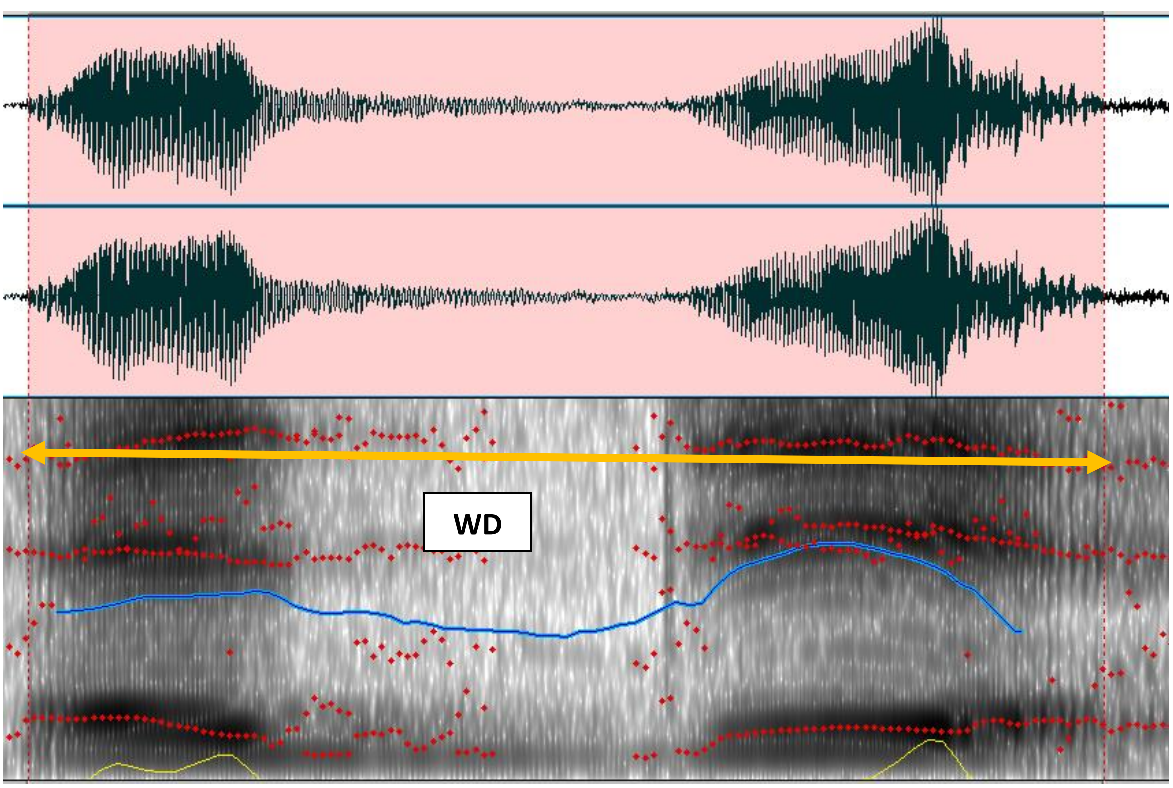
3) Vowel Duration

Word Duration (WD)

WD is the time difference between the onset and offset of the target word. WD was measured by placing the cursor on the onset and offset of the target word on the waveform. Figure 3.1. illustrates the measurement of WD.

Figure 3.1

Waveform showing WD of the word /ajji/

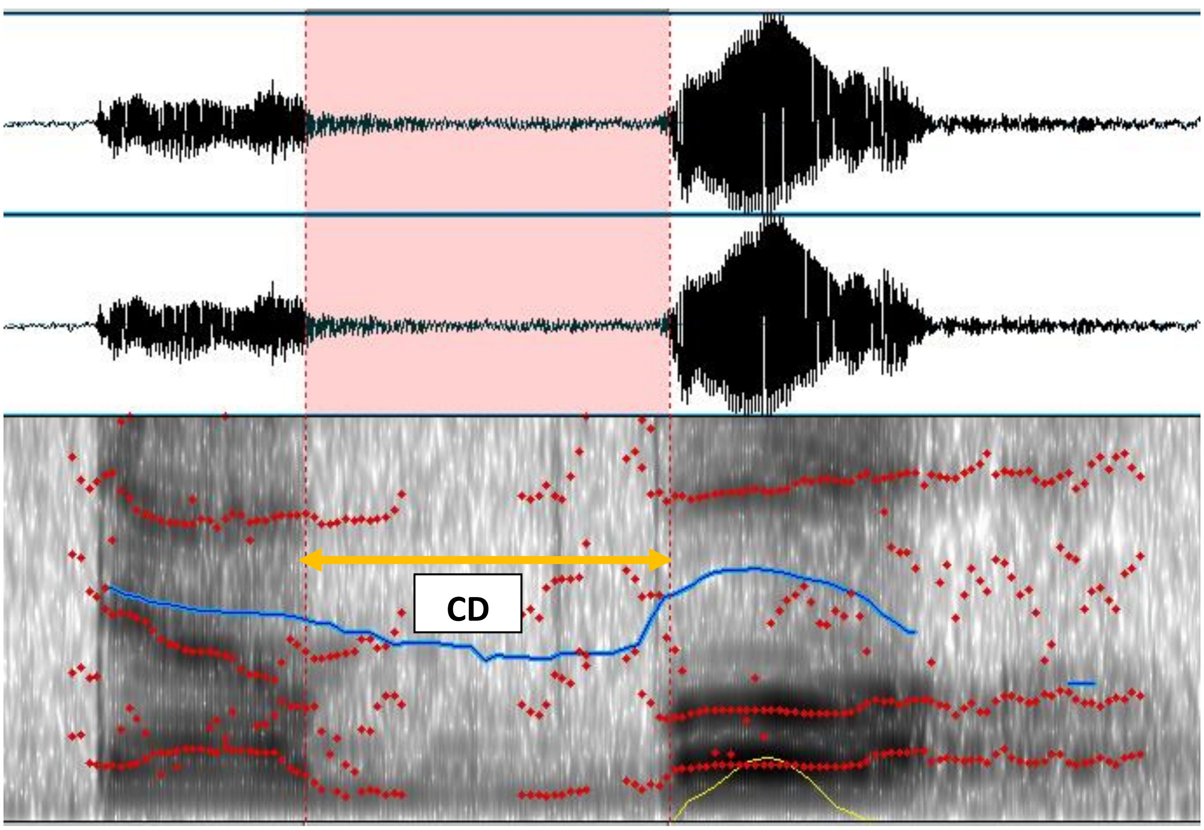


Consonant Duration (CD)

The time interval between onset of closure duration and onset of the following vowel was measured as the consonant duration in ms in the medial position. Figure 3.2 illustrates the measurement of Consonant Duration (CD).

Figure 3.2

Waveform showing CD of /b/ in the word /Kabbu/

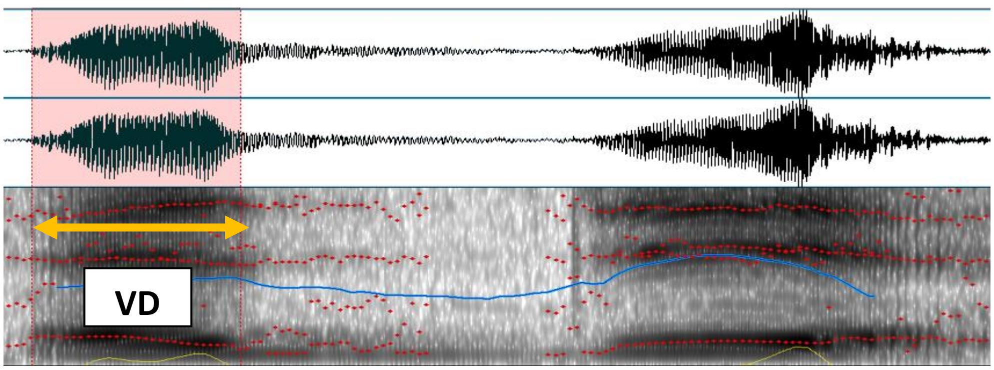


Vowel Duration (VD)

VD is the time difference between the onset and offset of the vowel. On the waveform, vowel onset was determined by the first steady visible pulse of the steady whereas vowel offset was determined similarly by the last steady visible pulse of the waveform. VD was measured in the word-initial position. Figure 3.3 illustrates the measurement of Vowel Duration (VD).

Figure 3.3

Waveform showing VD of /a/ in the word /ajji/



3.5 Statistical Analysis

The three temporal parameters were considered for the study among sixteen participants (8 Children with SSD & 8 typically developing children) were analyzed using PRAAT software. Statistical analysis was carried out using the Statistical Package for Social Science (SPSS) software (Version 20).

Inter and Intra judge reliability

Fifteen percent of the randomly selected samples were subjected to Inter and Intra judge reliability tests. To check the inter judge reliability three speech-language Pathologists including the researcher performed the acoustic analysis of the parameters independently. Whereas, for the intra-judge reliability the investigator herself analyzed the randomly selected samples at two different periods. The reliability coefficient (Cronbach's alpha) was calculated using SPSS and was found to be 0.96. Given that the Cronbach's alpha measure was found to be above 0.9, it is inferred that the analysis is adequately reliable.

CHAPTER IV

Results

The study aimed to analyze and compare the temporal characteristics of the speech of native Kannada speaking children with speech sound disorder (SSD) and age and gender-matched typically developing children (TDC). A total of sixteen (16) participants in the age range of 4 to 8 years were included for the present study. The participants were divided into two groups (Group I and Group II). Group I (Experimental group) consisted of 8 children with SSD in the age range of 4 to 8 years. Group II (Control group) consisted of 8 typically developing children, age, and gender-matched with the experimental group as the control group in the age range of 4 to 8 years.

The objectives of the current study were as follows:

1. To obtain the word duration in native Kannada speaking children with Speech Sound Disorder (SSD) and Typically Developing Children (TDC) in the age range of 4- 8 years and establish the difference in word duration between the groups.
2. To obtain the consonant duration in native Kannada speaking children with SSD and TDC in the age range of 4-8 years and establish the difference in consonant duration between the groups.
3. To obtain the vowel duration in native Kannada speaking children with SSD and TDC in the age range of 4-8 years and establish the difference in vowel duration between the groups.

The data was collected from 16 native Kannada speaking children including children with SSD and TDC in the age range of 4 – 8 years. The acoustic analysis of the collected sample was carried out using the PRAAT software (version 5.3.56) with a 44.1 kHz sampling frequency (Boersma & Weenink, 2019). The values obtained for each of the parameters were fed into SPSS software (version 20.0) for statistical analysis. Statistical analysis was carried out for word duration, consonant duration, and vowel duration measures as shown below:

4.1. Word duration measures

4.1.1. Mean and SD scores of word duration in SSD and TDC

4.1.2. Comparison of word duration between SSD and TDC

4.1.3. Reliability scores

4.2. Consonant duration measures

4.2.1. Mean and SD scores of consonant duration in SSD and TDC

4.2.2. Comparison of consonant duration between SSD and TDC

4.2.3. Reliability scores

4.3. Vowel duration measures

4.3.1. Mean and SD scores of word duration in SSD and TDC

4.3.2. Comparison of word duration between SSD and TDC

4.3.3. Reliability scores

4.1. Word Duration Measures

4.1.2 Mean and SD Scores of Word Duration in SSD and TDC

The descriptive statistical analysis was performed to obtain the mean and standard deviation (SD) values of word duration in children with SSD (Group I) and typically developing children (Group II). It shows that children with SSD had longer mean and SD values of word duration when compared to typically developing children. Considering the vowels in the study, word duration was found to be longest for words containing vowel /u/ in both groups; children with SSD (Mean = 749.17, SD = 123.55) and TDC (Mean = 600.65, SD = 94.44). The word duration was found to be shortest for words containing vowel /i/ in both groups; children with SSD (Mean = 509.79, SD = 122.77) and TDC (Mean = 430.79, SD = 56.54).

Considering the consonants included in the study, word duration was found to be longest for words containing the voiced retroflex consonant /ḍ/ in both groups; children with SSD (Mean = 816.58, SD = 136.32) and TDC (Mean = 792.08, SD = 90.35). The word duration was found to be shortest for words incorporating the bilabial consonant /p/ in children with SSD (Mean = 620.71, SD = 189.13) and for words containing unvoiced retroflex /ṭ/ in TDC (Mean = 545.54, SD = 123.79). The standard deviation was higher for dental /t/ in SSD and retroflex /ṭ/ in TDC. SD was lowest for vowel /i/ and /a/ respectively in both groups. Table. 4.1. depicts mean and SD scores of word durations for SSD and TDC.

Table.4.1

Mean and SD scores of Word Duration in Children with SSD and TDC

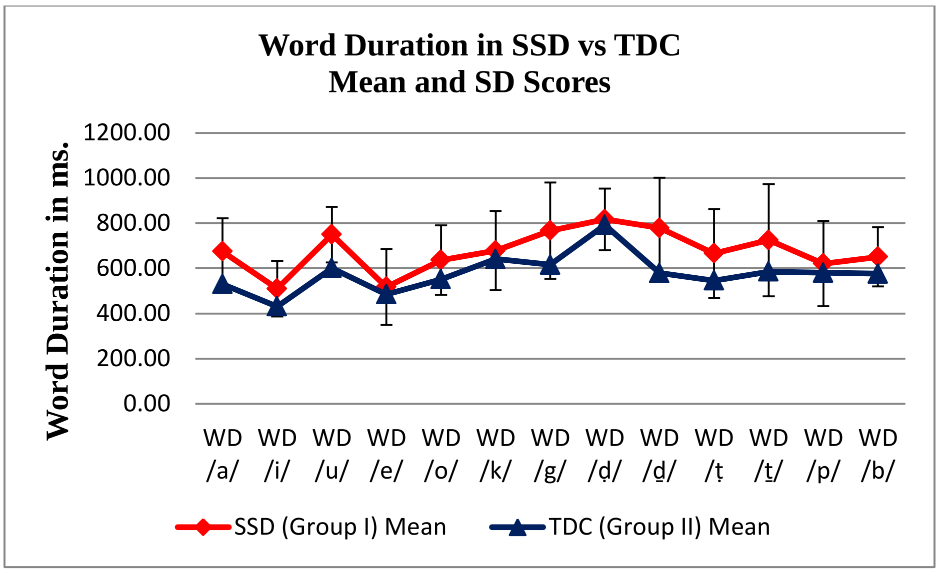
WD with vowels & Consonants	SSD (Group I)			TDC (Group II)		
	Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
/a/	674.21	146.41	646.67	529.67	43.91	525.17
/i/	**509.79**	**122.77**	**506.50**	**430.79**	**56.54**	**420.00**
/u/	**749.17**	**123.55**	**727.50**	**600.65**	**94.44**	**621.92**
/e/	517.17	167.70	522.33	484.71	73.13	490.67
/o/	636.50	154.24	635.17	551.25	90.99	523.33
/k/	678.00	175.24	707.33	641.29	60.24	623.67
/g/	766.63	213.61	729.67	615.33	86.07	627.17
/ḍ/	**816.58**	**136.32**	**831.17**	**792.08**	**90.35**	**825.00**

/d̪/	778.42	222.68	701.50	578.58	58.07	572.83
/ṭ/	665.92	196.49	734.50	**545.54**	**123.79**	**504.17**
/t̪/	724.65	248.53	716.00	585.42	58.21	564.00
/p/	**620.71**	**189.13**	**644.33**	580.21	79.96	561.67
/b/	650.58	130.62	651.00	575.83	79.79	576.33

Note. WD = Word Duration

Figure: 4.1

Mean Values of Word Duration in SSD and TDC



4.1.2 Comparison of word duration between SSD children and TDC

Using SPSS version 20.0 software, the data collected from both groups of children i.e., SSD (Group I) and TDC (Group II) were subjected to the Shapiro-Wilks test to find the normality of the data. The normal distribution of data was considered if the values (p) of Shapiro-Wilks were greater than 0.05. The results of Shapiro-Wilks tests showed that most of the variables had $p>0.05$. However, few variables had $p<0.05$. Non-parametric test i.e., Mann - Whitney test was used to compare these non-normal variables.

One-way MANOVA test (parametric) and Mann-Whitney test (Non-parametric) was done to compare the word duration between SSD children and TDC. As the variables, WD /a/, WD /i/, WD /u/, WD /e/, WD /o/, WD /g/, WD /d̪/, WD /ṭ/, WD /p/, WD /b/ exhibited normal distribution in Shapiro-Wilks test, One-way MANOVA was done. The results showed that word durations, i.e., WD /a/ (F= 7.15; *p*= 0.018), WD /u/ (F= 7.30; *p*= 0.017) and WD /d̪/ (F= 6.033; *p*= 0.028) had significant difference between two groups. Further, the Mann-Whitney test was run for variables WD /ḍ/, WD /k/, and WD /t̪/ which were not normally distributed. Results showed no significant difference ($p \leq 0.005$) between the two groups for the three variables. Hence, the null hypothesis stating that there is no significant difference for word duration between SSD and TDC groups are partially accepted. Table. 4.2 depicts F and p- values of word duration of SSD and TDC and Table. 4.3 depicts Z and p- values of the word duration of SSD and TDC.

Table. 4.2

Comparison of Word Duration between SSD and TDC using the MANOVA test

Word duration	**F -value**	***p*-value**
/a/*	**7.15**	**0.018***
/i/	2.73	0.121
/u/*	**7.30**	**0.017***
/e/	0.25	0.624
/o/	1.81	0.200
/g/	3.45	0.084
/d̪/*	**6.03**	**0.028***
/ṭ/	2.15	0.165
/p/	0.31	0.586
/b/	1.91	0.189

*Note: * significant difference (p≤0.005) in word duration between SSD and TDC.*

Table. 4.3

Comparison of Word Duration between SSD and TDC using the Mann-Whitney Test

Word duration	Z –value	*p* –value
/k/	-0.63	0.528
/ḍ/	-0.42	0.674
/t̪/	-0.74	0.462

4.1.3 Reliability scores of word duration in SSD and TDC

Cronbach's Alpha test was performed to test the reliability of word duration in children with SSD and TDC across the three trials. All the values were > 0.8 except WD /u/ in SSD and WD /p/ in TDC. This shows that there exists reliability in the data for word duration. Table 4.4 depicts the reliability scores of word duration in SSD and TDC.

Table 4.4

Reliability Scores of Word Duration in Children with SSD and TDC

Word duration	SSD	TDC
/a/	0.92	0.81
/i/	0.96	0.97
/u/	0.79	0.98
/e/	0.99	0.92
/o/	0.98	0.95
/k/	0.94	0.95

/g/	0.96	0.88
/ḍ/	0.99	0.9
/d̲/	0.99	0.95
/ṭ/	0.96	0.98
/t̲/	0.9	0.86
/p/	0.97	0.74
/b/	0.93	0.91

4.2. Consonant duration measures

4.2.1 Mean and SD scores of consonant duration in SSD and TDC

Descriptive statistical analysis was performed to obtain the mean and standard deviation (SD) values of consonant duration in children with SSD and typically developing children. It shows that children with SSD had longer mean and SD values of consonant duration when compared to typically developing children. The consonant duration was found to be longest for unvoiced bilabial /p/ for both groups; for children with SSD (Mean = 319.50, SD = 95.32) and for TDC (Mean = 264.25, SD = 37.99). The consonant duration was found to be shortest for voiced dental /d̲/ for children with SSD (Mean = 133.58, SD = 27.33) and voiced retroflex /ḍ/ (Mean = 42.21, SD = 5.68) for TDC. Standard deviation was highest for /p/ and /ṭ/ in SSD and TDC respectively. SD was minimum for retroflex /ḍ/ in both groups. Table 4.5 depicts mean and SD values of consonant duration for children with SSD and TDC.

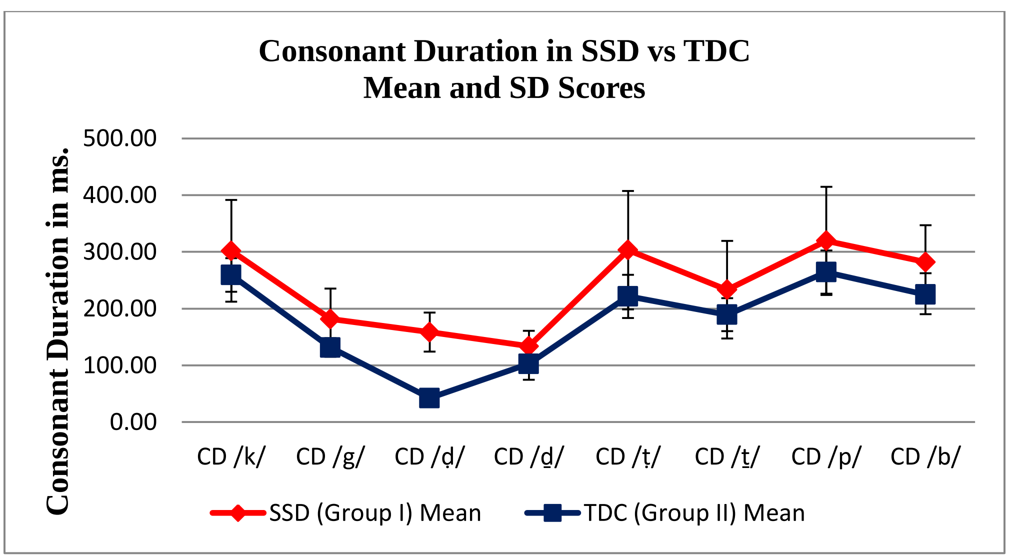
Table 4.5

Mean and SD Scores of Consonant Duration in SSD and TDC

	SSD (Group I)			TDC (Group)		
Consonant duration	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**
/k/	301.71	89.71	261.67	259.25	29.38	263.00
/g/	181.69	53.34	177.33	131.42	16.24	123.17
/ḍ/	158.50	34.42	149.00	**42.21**	**5.68**	**41.00**
/d̠/	**133.58**	**27.33**	**121.33**	102.71	27.83	109.67
/ṭ/	303.04	104.46	319.67	221.54	38.04	211.33
/t̠/	233.23	86.10	218.00	189.29	29.26	185.50
/p/	**319.50**	**95.32**	**299.33**	**264.25**	**37.99**	**270.00**
/b/	282.08	64.94	274.17	224.58	34.65	217.00

Figure 4.2

Mean values of Consonant Duration in SSD and TDC



4.2.2 Comparison of Consonant Duration between SSD and TDC

One way MANOVA test (parametric) and Mann-Whitney test (Non-parametric) was done to compare the consonant duration between children with SSD and TDC. As the variables, CD /k/, CD /g/, CD /ṭ/, CD /t̲/, CD /p/ exhibited normal distribution in the Shapiro Wilks test, one-way MANOVA was done. The results of one way MANOVA test showed that the consonant duration of voiced velar /g/ (F= 6.50; *p*= 0.023) was significantly different between the two groups. Further, the Mann-Whitney test was done in which variables CD /ḍ/, CD /d̲/, and CD /b/ are not normally distributed. The results of the Mann-Whitney test showed that consonant duration of voiced retroflex /ḍ/ (Z= -3.37; *p*= 0.001), voiced dental /d̲/ (Z= -2.00; *p*= 0.045) and voiced bilabial /b/ (Z= -2.10; *p*= 0.035) had significant difference ($p \geq 0.005$) between the two groups. It is observed that all voiced consonants considered were significantly longer in SSD. Hence, the null hypothesis for consonant duration stated that a significant difference between the two groups is partially accepted. Table. 4.6 depicts F and p- values of consonant duration of children with SSD and TDC and Table. 4.7 depicts Z and p- values of the consonant duration of children with SSD and TDC.

Table. 4.6

Comparison of Consonant Duration between SSD and TDC - MANOVA results

Consonant duration	**F -value**	***p* –value**
/k/	1.62	0.224
/g/*	6.50	0.023
/ṭ/	4.3	0.057
/t̲/	1.87	0.193

/p/	2.32	0.15

*Note: * indicates a Significant Difference (p≤0.005) in Consonant Duration between SSD and TDC.*

Table. 4.7

Comparison of Consonant Duration between SSD and TDC– Mann Whitney Results

Consonant duration	**Z -value**	***p* –value**
/ḍ/*	-3.37	0.001
/d̲/*	-2.00	0.045
/b/*	-2.10	0.035

*Note:*Significant Difference (p≤0.005) in Consonant Duration between SSD and TDC.*

4.2.3 Reliability scores of consonant duration in SSD and TDC

Cronbach's Alpha test was performed to test for between trial reliability of consonant duration for children with SSD and TDC. All the values were >0.8, except the consonant duration of voiced velar /g/ and voiced bilabials /b/ in children with TDC. This shows that there exists reliability in the data for the consonant duration. Table 4.8 depicts the reliability scores of consonant duration in children with SSD and TDC.

Table 4.8

Reliability Values of Consonant Duration in SSD and TDC.

Consonant duration	**SSD**	**TDC**
/k/	0.97	0.86
/g/	0.91	0.74
/ḍ/	0.96	0.86

/d̲/	0.95	0.94
/ṭ/	0.93	0.91
/t̲/	0.94	0.86
/p/	0.92	0.9
/b/	0.94	0.73

4.3 Vowel duration measures

4.3.1. Mean and SD of vowel duration in SSD and TDC

Descriptive statistical analysis was performed to obtain the mean and standard deviation (SD) values of vowel duration in children with SSD and typically developing children. It shows that children with SSD had longer mean and SD values of vowel duration when compared to typically developing children. The mean vowel duration was found to be longest for vowel /u/ in both groups: for children with SSD (Mean = 236.46, SD = 62.19) and for TDC (Mean = 178.79, SD = 29.93). The vowel duration was found to be shortest for vowel /o/ in both groups; for children with SSD (Mean = 108.50, SD = 41.16) and for TDC (Mean = 85.04, SD = 18.68). Standard Deviation of vowel duration was highest for vowels /a/ and /u/ and lowest for vowels /o/ and /a/ in SSD and TDC respectively. Table 4.8 depicts the mean and SD values of vowel duration for children with SSD and TDC.

Table 4.9

Mean and SD scores of Vowel Duration in Children with SSD and TDC

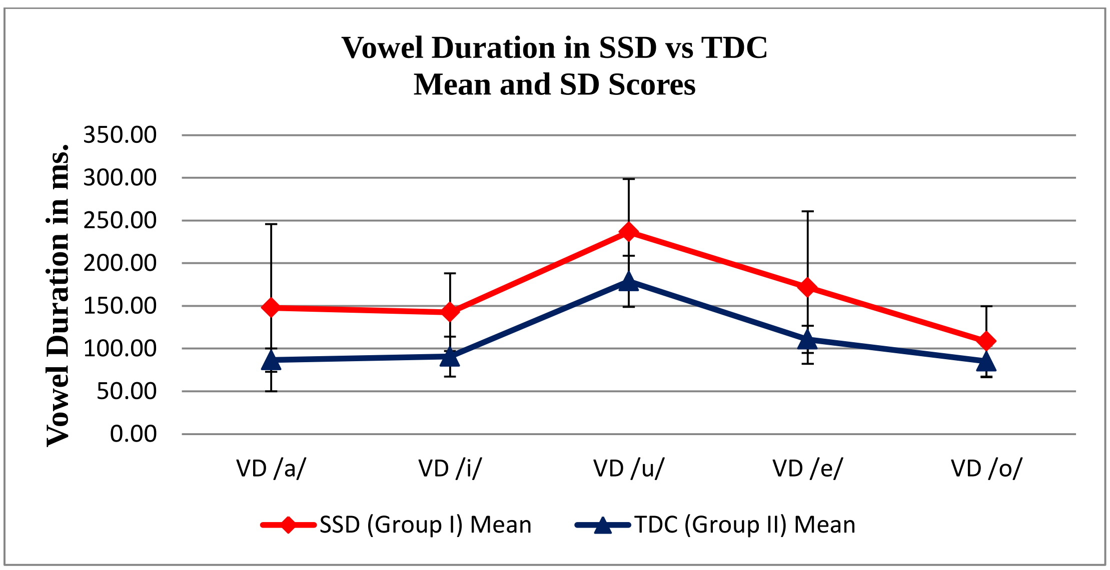
	SSD (Group I)			TDC (Group II)		
Vowel	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**

Duration

/a/	147.83	97.78	103.50	86.54	13.53	91.67
/i/	142.58	45.57	124.00	90.75	23.38	90.50
/u/	**236.46**	**62.19**	**237.83**	**178.79**	**29.93**	**175.67**
/e/	171.50	89.32	155.17	110.71	15.92	110.00
/o/	**108.50**	**41.16**	**85.67**	**85.04**	**18.68**	**77.17**

Figure 4.3

Mean values of vowel duration in SSD and TDC.



4.3.2 Comparison of Vowel Duration between SSD and TDC

One-way MANOVA test (parametric) and Mann-Whitney test (Non-parametric) was applied to compare the vowel duration between children with SSD and TDC. As the variables, VD /a/, VD /i/ and VD /u/ and VD /o/ exhibited normal distribution in the Shapiro Wilks test, one-way MANOVA was done. The results of the one-way MANOVA test showed that vowel duration of vowel /i/ (F= 8.19; *p*= 0.013) and vowel /u/ (F= 5.59; *p*= 0.033) showed significant difference between the two groups. Further, the Mann-Whitney test was run in variable VD /e/ as it was not normally distributed. The results of the Mann-Whitney test showed that the vowel duration of vowel /e/ (Z= -2.00; *p*= 0.046) was significantly different between the two groups. Hence, the null hypothesis stating there is no significant difference in vowel duration between SSD and TDC groups are partially accepted. Table. 4.9 depicts F and p -values (MANOVA) of vowel duration of children with SSD and TDC and Table. 4.10 depicts Z and p-values (Mann Whitney) of the same.

Table. 4.10

Comparison of Vowel Duration between SSD and TDC – MANOVA Results

Vowel duration	F –value	*p* -value
/a/	3.08	0.101
/i/*	8.19	0.013
/u/*	5.59	0.033
/o/	2.16	0.164

*Note: *significant difference (p≤0.005) in vowel duration between children with SSD and TDC.*

Table. 4.11

Comparison of Vowel Duration between SSD and TDC – Mann Whitney Results

Vowel duration	Z -value	*p* –value

/e/*	-2.00	0.046

*Note: * significant difference (p≤0.005) in vowel duration between children with SSD and TDC.*

4.3.3 Reliability scores of vowel duration in SSD and TDC

Cronbach's Alpha test was performed to test reliability across the three trials for vowel duration in children with SSD and TDC. All the values were >0.8 except VD /e/ and VD /o/ in children with TDC. This shows that there exists good reliability in the data for vowel duration as shown in Table 4.11.

Table 4.12

Reliability Scores of Vowel Duration in Children with SSD and TDC.

Vowel duration	**SSD**	**TDC**
/a/	0.99	0.84
/i/	0.86	0.9
/u/	0.94	0.98
/e/	0.99	0.79
/o/	0.93	0.78

To summarize the results of the present study, it can be stated that though the temporal measures of word duration, consonant duration, and vowel duration are longer in children with SSD, not all measurements were significantly longer compared to age and gender-matched typically developing children. Only 10 measures out of a total of 26 were found to be significantly different between the two groups. For word duration, words containing vowels /a/ and /u/ and consonant /d̲/ had a significantly longer duration.

For the consonant duration, velar /g/, dental /ḍ/, retroflex /ḏ/ and bilabial /b/ had significantly longer duration in SSD, i.e., all voiced consonants were longer. Vowel duration was significantly longer for vowels /i/, /u/ and /e/ in SSD compared to TDC.

CHAPTER V

Discussion

The present study aimed to compare the temporal characteristics of the speech of native Kannada speaking children with speech sound disorder (SSD) and age and gender-matched typically developing children (TDC). A total of 16 participants in the age range of 4 to 8 years participated in the study. The participants were divided into two groups (Group I and Group II). Group I (Experimental group) consisted of 8 children with SSD and Group II (Control group) consisted of 8 typically developing children, age, and gender-matched with the experimental group in the age range of 4 to 8 years. The temporal parameters of word duration, consonant duration, and vowel duration were extracted and compared across the experimental and control groups. The results of the study had some salient findings and they are supported by several earlier literature reports as discussed below.

5.1 Word Duration Measures

The results of the current study showed that children with SSD had longer word duration when compared to typically developing children. In accordance with the present study, a similar study by Macrae et al. (2010) stated that children with SSD had longer word duration than NSSD (No Speech Sound Disorder) because children with SSD showed delayed neuromotor maturation co-occurring with their delayed speech production. That is despite simplifications in the articulation of word forms, the motor control underlying the articulations would indicate a generalized delay in speech motor control. This study proposed that delayed speech motor skills were a contributing factor in SSD. Another study by Collins et al., 1983, revealed that apraxic speakers had significantly longer word duration than normal speakers. They suggested that it could be due to the disrupted speech in apraxia that s required greater production time; the temporal relationships were surprisingly well preserved while producing the articulatory sequences which increased in length from one to three syllables. It is possible that the SSD participants in the present study also had comorbid apraxic components.

5.2 Consonant Duration Measures

The result of the present study showed that children with SSD had longer consonant duration for voiced consonants when compared to TDC. In support of this finding, a similar study by Munson (2004) on the duration of /s/ frication, and its variability in adults and three groups of children, found that children had a larger temporal variability than adults. Another study by Weismer and Elbert (1982) studied the temporal characteristics of /s/ production in normally speaking adults, normal speaking children, and children with /s/ misarticulation. They found that /s/ durations of the misarticulating children were significantly more variable than those for the other two groups. It suggested that differences in speech motor control capabilities; temporal variability reflects both maturation and disorder. Another study by Catts and Jensen (1983) stated that some phonologically disordered subjects failed to differentiate VOT in word-initial voiced and voiceless stops, whereas others produced much longer VOTs for voiceless stops than did normal subjects. In the word-final voicing contrast, the phonologically disordered children evidenced longer consonant closure durations and less voicing during consonant closure than did normal subjects. It suggested that phonologically disordered children may have less mature speech timing control. A study by Freeman, Sands, and Harris, (1978) stated that VOTs of apraxic subjects differed markedly from normal subjects. The apraxic productions did not include voicing lead for voiced stops. Lag times for voiced stops were longer than normal, while those for voiceless stops were shorter than normal, yielding a compression of the two categories and a marked overlap.

5.3 Vowel Duration Measures

The results of the present study showed that vowel duration was significantly longer in children with SSD when compared to TDC. In support of the present study, a similar study by Macrae, Gillon, and Robb (2010) stated that children with SSD had longer vowel duration than NSSD (No Speech Sound Disorder) because children with SSD showed delayed neuromotor maturation co-occurring with their delayed speech production. That is despite simplifications in the articulation of word forms, the motor control underlying the articulations would indicate a generalized delay in speech motor control. This study suggested that delayed speech motor skills were a contributing factor in SSD. Another study by Collins et al., 1983, revealed that apraxic speakers had significantly longer vowel duration than normal speakers. They suggested that it could be due to the disrupted speech in apraxia, requiring greater production time; the temporal relationships are surprisingly well preserved while producing the articulatory sequences which increased in length from one to three syllables. In the literature, several other studies also supported the present study. Strand et al. (1996) found that apraxic speakers exhibited significantly longer vowels and between word segment durations than normal speakers. They justified that it may be due to a combination of a poorly specified or realized spatial target, motor command, acoustic template, or coordinative structure as well as insufficient feedback about the movement. Such a combination of processing deficits may contribute to the prosodic difficulty in apraxic utterance production. Kent et al. (1983) found that apraxic productions were “extremely lengthened relative to the normal production, for many of their apraxic patients, segments, word (or) sentence durations were two, three, or more times as long as those for normal speakers. This also supports the current study.

On the other hand, contradicting the current study, DiSimoni et al. (1977) analyzed the duration of vowels and consonants in four phonemic contexts for apraxia of speech and normal subjects. They found vowel durations were significantly shorter, but consonant durational patterns were much more variable than normal and did not appear to be lawful. A study by DiSimoni et al. (1977) revealed that apraxic speakers failed to follow the normal pattern and it was significantly shorter in duration. They suggested that the rate of movement in the intrasyllabic condition was more rapid in the apraxic speaker than in normal speakers and the apraxic speaker may grossly overestimate the size of the unit to be programmed. Another report by McNeil et al. (1991); Robin et al. (1989), and McNeil et al. (1989) contradicts the current study stating that apraxic speaker’s highest velocities of lip and jaw movements during a speech to be within the normal range. This finding suggested that increased segment durations were not necessarily due to a generalized slowness of all articulatory movement. A more reasonable explanation is that apraxic speakers extend steady states, perhaps to reach specific articulatory configurations. Hence the current study mostly supports the earlier studies in terms of temporal deviations in SSD, though is in contradiction to some others.

CHAPTER VI

Summary and Conclusions

The present study aimed to analyze and compare the temporal characteristics of the speech of native Kannada speaking children with speech sound disorder (SSD) and age and gender-matched typically developing children (TDC).

The main objectives of the study were

1) To obtain the word duration in native Kannada speaking children with Speech Sound Disorder (SSD) and Typically Developing Children (TDC) in the age range of 4- 8 years and establish the difference in word duration between the groups.
2) To obtain the consonant duration in native Kannada speaking children with SSD and TDC in the age range of 4-8 years and establish the difference in consonant duration between the groups.
3) To obtain the vowel duration in native Kannada speaking children with SSD and TDC in the age range of 4-8 years and establish the difference in vowel duration between the groups.

A total of sixteen (16) participants in the age range of 4 to 8 years were included for the present study. The participants were divided into two groups (Group I and Group II). Group I (Experimental group) consisted of 8 children with SSD (Phonetic type) and Group II (Control group) consisted of 8 typically developing children, age and gender-matched with the experimental group as the control group in the age range of 4 to 8 years. The test stimuli include a total of 13 words with 5 words for vowel measures and 8 words for consonant sound measures. Five vowels, /a/, /i/, /u/, /e/, /o/ and eight unaspirated stop consonants including both voiced and unvoiced were considered as target phonemes. Target words were selected from KDPAT (Deepa et al. 2010) which were picturable, unambiguous, and within children's vocabulary. The vowel duration was measured in the initial position and the consonant duration was measured in the medial position of the target words. The picture stimuli were presented on a laptop computer screen. The participants were instructed to name each of the 13 target words for three trials in random order. Those children who were unable to name the picture shown, they were asked to repeat after the clinician. The testing was carried out before the speech therapy intervention initiated for Group 1 (children with SSD). The child's performance was audio-recorded using the high-quality recorder (Olympus multi-track linear PCM recorder Model No: LS 100). The picture stimuli were randomly arranged to elicit the three trials of 13 stimuli considered. The recorded speech samples were analyzed using PRAAT software version 5.3.56 (Boersma & Weenink, 2010). The temporal measures (word duration, consonant duration, and Vowel duration) were measured from the waveform. All three productions of each stimulus were measured, and the average was considered. Fifteen percentages of randomly selected data from overall were subjected to inter-judge and intra-judge reliability: it showed good to excellent reliability.

Obtained data were subjected to descriptive statistics to obtain the mean and standard deviation of the variables considered. Most of the variables showed normal distribution and thus, parametric test (MANOVA) was applied. However, few variables had non-normal distribution. So, non-parametric test (Mann-Whitney) was applied for these variable for further group comparisons. The result of the present study suggests temporal parameters like word duration, consonant duration, and vowel duration were found to be significantly longer in SSD compared to TDC, but not all measurements were significantly longer compared to age and gender-matched typically developing children. Only ten measures out of a total of 26 were found to be significantly different between the two groups.

Children with SSD showed significantly longer word duration, consonant duration and vowel duration compared to typically developing children. This may be due to delayed neuromotor maturation co-occurring with their delayed speech production and simplifications in the articulation of word forms, the motor control underlying the articulations would indicate a generalized delay in speech motor control in children with SSD. The longer duration in temporal measures may be possibly because children with SSD would require greater production time and also they may have less mature speech timing control.

Clinical Implications:

1. The study addresses the issue of an objective description of children's functional misarticulation and will provide insights into the segmental aspects such as word, consonant, and vowel durations among native Kannada-speaking children with and without SSD.
2. This study will address the problem with an objective to improve the underlying speech-motor deficits associated with SSD
3. The temporal measures could provide a sensitive metric for the evaluation of the neuromuscular maturation of the speech mechanism in children with SSD

4. The study provides some insight into the oral sensory perception of children with SSD
5. Deficits in vowel articulation should not be overlooked in children with SSD. Therefore including correct vowel production as a treatment goal would facilitate overall improvement in phonological skills and speech intelligibility
6. The study will also aid in the differential diagnosis of SSD. Children with longer segment durations are likely to fall into the category of Apraxia of Speech (CAS). Such differentiating features are necessary to plan a systematic assessment and treatment protocol for SSD.

Limitations

- The current study included children in the age range of 4-8 years, thus, cannot be generalized to younger and older children.
- The study included only 8 participants
- The current study did not rule out any apraxic components in participants with SSD.

Future recommendations

- The study can be considered with a large sample size in different age groups of children with SSD.
- Further study including other acoustic measures can be considered.

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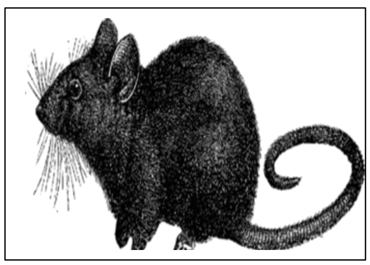
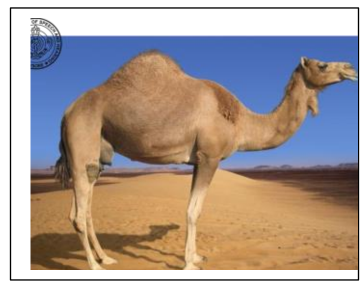
APPENDIX - I

Stimuli (Vowels) considered for the study

(Source: *Kannada Diagnostic Photo Articulation Test*

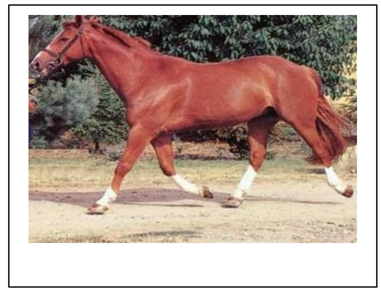
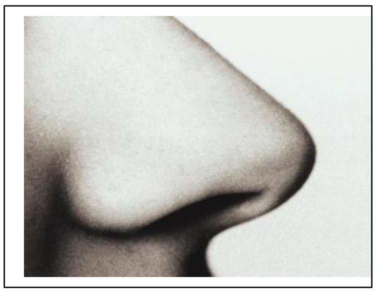
Deepa and Savithri, S.R. 2010)





Stimuli (Consonants) considered for the study
(Source: *Kannada Diagnostic Photo Articulation Test*

Deepa and Savithri, S.R. 2010)




Appendix – II

Sample of consent form

Informed consent taken from parents/caregiver

I Ms. Sudharsana S, 2nd M.Sc. SLP fellow, am doing research as a part of dissertation on "**Temporal characteristics of speech in children with speech sound disorder: An exploratory study**". During the course of research I have to collect only the speaking samples. There are no risks or discomforts involved during the study. Audio recording the sessions will be done and these recordings will be kept confidential. The participation in the study is voluntary and there is no compulsion.

Informed Consent

I have been informed about the study and understand its purpose and my child's participation in it. The possible benefits of my child's participation as human subject in the study are clearly understood by me. I understand that I have a right to refuse participation as subject or withdraw my consent at any time. I give my consent for my child's/student participation in this study.

I, ______________________________, the undersigned, give my consent for my child's participation in this study.

(AGREE/DISAGREE)

Signature of Parent/Teacher

(Name and Address)

Signature of Investigator

(Name and Designation)