EFFECT OF PHONETIC FACTORS AND GENDER ON DURATION OF STOP CONSONANTS IN TELUGU

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Registration Number: 12SLP027

A Dissertation Submitted in Part Fulfillment of Final Year

Master of Science (Speech-Language Pathology)

University of Mysore, Mysore.

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CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Phonetic Factors and Gender on Duration of Stop"*** is a bonafide work submitted in part fulfilment for degree of Master of science (Speech- Language Pathology) of the student Registration No: 12SLP027. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
May, 2014

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CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Phonetic Factors and Gender on Duration of Stop"*** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for award of any Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled ***""Effect of Phonetic Factors and Gender on Duration of Stop"*** is the result of my own study under the guidance of Prof. S.R. Savithri, Director, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other university for the award of any Diploma or Degree.

Mysore,
May, 2014

Registration No. 12SLP027

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ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere gratitude to my guide, Dr. S.R. Savithri, Director of AIISH for her valuable support, guidance during my study. In spite of the busy schedule as a director, thank you madam for patiently listening to my doubts and giving me valuable suggestions. Madam you are my inspiration and I am very happy to be your student.

I thank all my subjects who had participated whole heartedly for my study.

I thank Dr. Yeshoda madam for teaching acoustics of speech production very clearly and encouraged us to do studies in this area.

I thank Dr. Jayashree madam, for being the CBCS coordinator and motivating us to submit all the documents on time.

I am grateful to all the staff, Sreedevi madam, Rajasudhakar sir, Geetha madam, Swapna madam and R. Manjula madam for all the research input I have received during their classes.

I would also like to express my heartfelt thanks to Jaya kumar sir, Santhosh sir, Navya madam and Pushpavathi madam for helping with my research when I was still in the budding stage.

I AM THANKFUL TO VASANTHALAKSHMI MADAM FOR HELPING ME WITH THE STATISTICAL ANALYSIS.

THANK YOU MAHATHI AND RAJINI FOR YOUR VALUABLE CONTRIBUTION AS TWO JUDGES FOR MY STUDY. I WOULD LIKE TO THANK SAMPATH SIR FOR HELPING ME DURING WORD SELECTION FOR MY STUDY.

I AM VERY THANKFUL TO MY DEAREST FRIEND, RAMYA MAHATHI FOR ALWAYS BEING WITH ME AND LEADING ME THROUGH THE RIGHT PATH.

I THANK ALL MY CLASSMATES FOR THE FUN WE HAD IN THESE TWO YEARS.

MY SPECIAL THANKS TO MY PARENTS, GRANDPARENTS FOR THEIR WELL WISHES AND PRAYERS FOR COMPLETION OF MY DISSERTATION.

LAST, BUT NOT THE LEAST, I AM VERY THANKFUL AND GRATEFUL TO MY GURUDEV FOR BEING WITH ME AND GIVING ME COURAGE TO FACE ALL THE CHALLENGES IN LIFE AND GIVING LOT OF ENERGY TO DO ALL THE THINGS EFFORTLESSLY. THANK YOU GURUJI FOR BEING IN MY LIFE. I ALSO THANK TEACHERS AND VOLUNTEERS OF ART OF LIVING FOR ALLOWING ME TO SERVE BY CONDUCTING COURSES IN THIS COLLEGE.

CHAPTER I

INTRODUCTION

The speech sounds of language can be categorized as vowels and consonants. Vowels are produced with least constriction in oral tract, where as consonants are formed by making a construction at some point between glottis and the lips. Consonants range from those creating no pressure build-up in vocal tract (sonorants) to those which have complete closure of vocal tract, resulting in considerable pressure build-up (obstruent). The majority of speech sounds including vowels, sonorants and fricatives, contain a steady-state time period in which sound is continually generated. The only two classes of speech sound that contain no steady state are stops and affricates. These two obstruent's types are characterized by acoustic properties that change rapidly with the progression of time and hence can be described by sampling the acoustic properties at a series of time intervals. It is easy to study the production of steady state sounds, owing to the low frame rate of many of available measurement techniques. However, it is difficult to study the production of stops and fricatives, the properties of which keep changing with time. As a result, there is not much information available about the detailed production and acoustics of stop consonants and fricatives.

Oral stop consonants are produced by a complete occlusion in the oral cavity where airflow is briefly yet completely stopped. When oral stops are produced the velopharyngeal port is closed preventing air from escaping through the nasal passages. These stops are also called plosives because of the transient burst of sound that exists after the release of constriction. Stop consonants are considered to be special in that they have a closure (period during which the oral cavity is closed),

burst (broadband noise transient), frication (high frequency noise), aspiration (low frequency noise), and transition into the following vowel. Stops can be voiced or unvoiced. Closure is visible in word-initial voiced stop consonants but no so in word-initial unvoiced stop consonants.

Duration is an important aspect of the message comprehended. Several studies on the durational structure of speech sounds have been conducted which reveal marked variations as well as small variations in the segmental durations (Carlson & Granstrem, 1973). “Variations in segment duration are important cues of acoustic variability in the realization of linguistically identical units. Physical measurements on the articulatory and acoustic aspects of speech production indicate the regularities in the timing of speech. Those regularities are found to be language specific and thus reflect learned aspects of verbal behavior. A study of such regularities may lead to the formulation of rules which model part of the knowledge, the speaker has about his language. The physical measurements would be the best way to gain insight into the structures of language" (Nooteboom, 1973). Further, durational data could be used to understand the nature and organization of speech production, speech perception and phonological theory (Kozhevnikov & Chistovich, 1965). The durational patterns reflect the speaker's mood, speaking rate and the locations of the emphasized material. The phonetic identity of different types of segment is cued by their duration (Klatt, 1976). Perceptual studies of natural and synthetic speech that have been altered with regard to temporal aspects (Huggins, 1972; Nooteboom, 1971) indicate that the listener can perceive very small changes in segmental duration as deviant. Duration plays another kind of role in speech perception. The speech sound heard is determined by the duration of gradually changing speech event such as a formant transition

(Liberman, Delattre, Gerstman & Cooper, 1956; Suzuki, 1970). It has been reported that duration can effectively disambiguate syntactically ambiguous sentences even in the absence of cues provided by fundamental frequency and pauses (Lehiste, Olive & Streeter, 1976). In addition, durational data may be of use in applied research areas such as automatic generation of speech for a reading machine for the blind and the automatic recognition of speech from the acoustic waveform.

Durations of different segments vary widely depending upon several factors. Klatt (1976) classified these factors as (1) Extralinguistic factors, (2) Discourse level factors, (3) Semantic factors, (4) Syntactic factors, (5) Phonetic factors, and (6) Physiological factors.

Under the ***extralinguistic factors***, Klatt (1976) includes speakers' mood, their physical Condition, age, and sex, and speaking rate. Speaker's mood and physical condition influences the duration of speech sounds. Williams and Stevens (1972) have shown that actors, attempting to simulate various emotional states, speak differently in different emotional conditions. They speak very slowly when angry and slower than normal when expressing fear or sorrow. Persons' speaking rate also tends to change the durational patterns. Huggins (1964) had reported that, increase in the speaking rate may results in shortening of vowels and consonant duration. Duration of speech sounds also changes depending on the age of the speaker. Sweetings (1980) found that the vowel duration increased with the age of the speaker.

Discourse level factors include the duration difference between non-final and final sentences in reading passage (Klatt, 1976). Klatt (1976) reported that, there was a difference in duration between final and non-final position of the sentence in reading, which was 2260 ms and 1390 ms, respectively.

Semantic factors include emphasis or contrastive stress and semantic novelty which play an important role in change in the duration of speech sound. The acoustic correlates of emphasis in an increase in the duration of the word. A Study by Savithri (1986) indicated that the duration of vowel was longer when stressed. Umeda (1975) has shown that semantic novelty has an influence on segmental durations in the sense that an unusual word is longest the first time that it appears in a connected speech.

Syntactic factors include Phrase structure lengthening and Prepausal lengthening**.** Gaitenberg (1965) found that the syllable at the end of the sentence was longer than the syllable within the sentence. The syllables before the pause are lengthened when compared to syllable in other positions (Klatt, 1976). Lindblom and Rapp (1973) observed that there was a lengthening of the speech segment at the end of the linguistic unit.

Phonetic factors include several factors such as aspiration, voicing, position of consonant in the word, and place of articulation. The aspirated consonants are longer (160 ms) than the unaspirated consonants (110ms) (Savithri, 1984). The duration of the unvoiced consonant is longer than that of the voiced (Klatt, 1976; Sthathopoulous & Weismer, 1979). Fintoft (1961) found that the unvoiced fricatives of Norwegian speech sounds were always longer than any other consonants. Word initial consonants are longer than non-initial consonants (Klatt, 1976). In Kannada the duration of consonants in the word- medial position was shorter than those in the word-initial position (Rajapurohit, 1982). In Sanskrit it was observed that the retroflex consonants were the shortest in duration when compared to consonants with other places of articulation (Savithri, 1983).

Physiological efforts have been used to explain the difference in inherent phonological durations of vowels. For example, the longer duration of low vowels has been attributed to the extra effort to open the jaw in the context of a consonant (Lindblom & Studdert-Kennedy 1967).

Botinis, Christofi, Themistocleous & Kyprianou, (2004*)* studied the duration of stop consonant as a function of voice, length, stress, syllable position, speech tempo and speaker's gender in Cypriot Greek. The results indicated that, the voiced stop occlusion was 21% longer than the voiceless stop occlusion, the voiceless stop burst was 32% longer than the voiced stop burst and the total voiced and voiceless stop durations were fairly the same. Distinctive length production function showed that, the long stops were totally 78% longer than the short stops. The long voiceless stop occlusion had fairly the same duration with the voiced stop occlusion but 42% more than the short stop occlusion. The long stop burst was 39% longer than the short stop burst and 51% longer than the voiced stop burst. Distinctive stress production effect indicated that, the stressed stops were 13% longer than the unstressed ones and this difference was 15% with reference to stop occlusion. Syllable position production effect showed that, the penultimate stops were 6% longer than the ultimate stops and the penultimate stop occlusion was 8% longer than the ultimate one. Speech tempo production effect indicated the normal tempo stops to be 25% longer than the fast tempo ones; stop occlusion to be 27% longer than the fast tempo one and stop burst to be 17% longer than the fast tempo one. Speaker's gender production effect indicated female stop production to be 6% longer than the male stop production and the female stop occlusion to be 9% longer than the male stop occlusion. In contrast, Vicenik (2010) conducted an acoustic study of Georgian stop consonants and reported no main

effect of stop type at any place of articulation for closure duration. Bilabial stops showed the longest average closure duration than alveolars and velars.

Results of some studies indicate durational differences between dialects. Samantha (2008) reported longer closure duration in Wisconsin dialect of American English compared to North Carolina dialect (110 ms vs. 101 ms).

The results of these studies indicate that, the duration depends on several factors within a language, between languages, and within dialects. Further, the duration depends on voicing and aspiration. Some of the Indian languages are different from English in voicing and aspiration. In English aspiration is phonetic where as in many of the Indian languages it is phonemic. Further, several of the Indian languages have four-way classification of stop consonants (Voiced murmured, voiced unaspirated, unvoiced aspirated, unvoiced unaspirated) where as English has two-way classification of stop consonants (Voiced unaspirated, unvoiced unaspirated). Also, while English has three places of articulation for stop consonants, several of the Indian languages have four places of articulation. These differences necessitate one to investigate the duration of stop consonants in Indian languages. In this context, the present study investigated the effect of phonetic factors on duration of stop consonants in Telugu [*Telugu is a Dravidian language predominantly spoken in the Indian state of Andhra Pradesh where it is an official language. It is also spoken by significant minorities in the states of Chhattisgarh, Karnataka, Maharashtra, Odisha, Tamil Nadu, and in Yanam, in the union territory of Pondicherry. One of the four classical languages of India, Telugu ranks third by the number of native speakers in India (74 million), thirteenth in the Ethnologic list of most-spoken languages worldwide, and the most spoken Dravidian language. It is one of the twenty-two scheduled languages of the Republic of India. Retrieved from https:en.wikipedia.orgwiki*]. Specifically, the effect of

phonetic factors – voicing, preceding vowel, aspiration and place of articulation – on duration of stop consonants in 18-30 year old Telugu speakers from Telangana dialect was investigated. Furthermore, the effect of gender on the duration of stop consonants was investigated. The unvoiced unaspirated stops in Telugu include /p/, /t/, /ʈ/, /k/ and the voiced unaspirated stops are /b/, /d/, /ɖ/, /g/. Stops in Telugu can also be aspirated murmured and unaspirated. Unvoiced aspirated stops include p^h, t^h, $ʈ^h$, k^h and the voiced murmured stops are b^h, d^h, $ɖ^h$, g^h.

Results of the study would have the following implications:

1. This study provides the temporal description of all the Telugu stop consonants in 18 to 30 years age group in females and males. Hence, gender difference of these measures can be obtained.

2. This information can be used in evaluating the speech deviation of patients with various speech disorders.

3. The data obtained is useful in synthesizing Telugu speech sounds and recognition of the same.

4. The study also provides information on the effect of various vowels on the stop consonants.

CHAPTER II

REVIEW OF LITERATURE

The review will be dealt under the following headings:

(1) Effect of voicing on duration of stop consonants

(2) Effect of preceding vowel on duration of stop consonants

(3) Effect of aspiration on duration of stop consonants

(4) Effect of place of articulation on duration of stop consonants

(5) Effect of gender on duration of stop consonants

(1) Effect of voicing on duration of stop consonants

Stop consonants are produced by a brief articulatory closure, during which the air pressure continues to build up behind the constriction and released finally by sudden opening of the constriction. The release is usually accompanied by a burst of frication noise as air rushes through the narrow constriction, creating turbulence noise. The opening at the constriction continues to increase, until finally it becomes large enough such that turbulence noise can no longer be generated.

For the voiced in many languages, voicing may continue throughout the release, and after the burst of frication noise, normal voicing of the following vowel commences. Whereas, for the voiceless stops, there is no spontaneous voicing before the release, the vocal cords are apart. As the constriction opens, the vocal cords are brought closer to each other, and the tension of the cords is also adjusted so that voicing for the following vowel takes place.

Durational measures of the stop consonants include closure duration, burst duration and total consonantal duration. The closure duration is measured from the end of the preceding vowel to the release which is generally marked by a sharp increase in acoustic energy. The burst duration is measured from the onset to the offset of burst release. The total duration is measured from the end of the preceding vowel to the beginning of following vowel, where the time waveform first shows signs of periodicity following the release.

The first acoustic study to measure the duration of stop consonants was conducted by Lisker (1957) to find difference in closure duration in voiced - voiceless contrast of English stops in which duration of intervocalic labial stops as in words such as rabid and rapid were analysed using spectrographic measurements. Results suggested that, the closure duration of intervocalic labial stop was shorter for voiced stop, as in rabid, than in the voiceless stop, as in rapid which was 75 ms and 120 ms, respectively. Similar results was found by Sharf (1962) who reported that mean closure duration was 92 and 60 ms for /p/ and /b/, respectively.

Luce and Luce (1985) investigated the closure duration of word final stop consonant in CVC combination in English meaningful words. Results reveal closure durations were longer for the voiceless stops than voiced stop consonants.

Savithri, (1986) studied duration of stop consonants in Kannada as an effect of voicing. Three male and three female Kannada speakers in the age range of 22-40 years were participated in the study. Participants were instructed to read list

of 83 meaningful trisyllabic Kannada words which consisted of medial target stop consonants. These reading were audio recorded duration of the consonants were measured. Results revealed that, the voiceless stops were longer than the voiced stops with mean duration of 186msecs and 154msecs respectively. Davis, and Summers (1989) studied the closure duration of voiced and unvoiced stop consonants (/b/,/d/,/g/ and /p/,/t/,/k/) in word medial VCV nonsense syllables sequence in English language showed that, closure durations were longer for voiceless stops that voiced stop consonants.

Byrd (1993) analysed 24,414 oral stop closures in American English as a TIMIT database which shows that, the closure duration of voiceless bilabial and velar stops are significantly longer than voiced counter part. But there was no significant difference between voiced and unvoiced alveolar stops. This study also investigated voicing effect on burst duration of 21,847 stops and reported that, there was significant effect of voicing on burst duration indicating that, burst duration of voiceless stops was longer than voiced with mean release duration of 22ms and 49ms for voiced and voiceless stops respectively.

Ghavami (2002) measured the closure duration in singleton versus geminate stops for American English and Persian speakers. Results revealed that the closure durations of voiced stops were uniformly smaller than their voiceless aspirated counterparts in both singleton and geminate forms in English and in Persian consonants of all places of articulation except for /bb/.

(2) Effect of preceding vowel on duration of stop consonants

Preceding vowel is one of the phonetic factors influencing segmental duration.

There are very few studies reporting the influence of preceding vowel on the duration of stop consonants. Chen (1970) investigated the difference in the duration of vowels when preceded by voiced and unvoiced stop consonants in Korean, English, French, and Russian languages. Results indicated that, the voiced stops were always followed by longer vowels and voiceless stops were followed by shorter vowels in all the languages. He claimed that there were large differences among these languages in the magnitude of the contrast, with native English speakers showing the greatest contrast, followed by French, Russian, and Korean. Considering further languages, Madieson (1977) investigated the effect of preceding vowel on voiced vs. unvoiced and aspirated vs. unaspirated stops in Assamese, Bengali, Hindi, Marathi, and Eastern Armenian languages and found that, in all the languages voiced stops were always preceded by long vowels and voiced stops were preceded by short vowels. Aspirated stops were preceded by longer vowels and unaspirated stops were preceded by short vowels.

Raphael (1972) investigated the ***effect of preceding vowel duration on the perception*** of voiced and unvoiced word-final stops where a variety of minimal CVC word pairs were synthesized with varying vowel duration and presented to 25 normal hearing listeners over a loud speaker in a sound treated room. Subjects were instructed to respond in a forced-choice format and label which word was heard in the minimal pair. Results revealed that, regardless of voicing cues used in the synthesis of the final stop consonant, listeners perceived the final segment as voiceless when they were preceded by vowels with shorter duration and as voiced when they were preceded by vowels with longer

duration.

Kim and Macneilage (1972) analysed the voiceless stop duration in VCV utterances using digitized oscillographic displays. Eight subjects produced each consonant 10 times in each of the four contexts i-i, i-a, a-i, and a-a. In general, duration of stop consonants was shorter when followed by low vowels and stop duration was longer when followed by high vowels. But, these durational effects of the preceding vowel were not consistent across subjects.

Savithri, (1986) studied effect of preceding vowel on the duration of stop consonants in Kannada. Three male and three female Kannada speakers in the age range of 22-40 years participated in the study. Readings of the word list consisted of 83 meaningful trisyllabic Kannada words with medial target stop consonants of all the participants were recorded and duration of the consonants was measured. Results indicated no significant difference between the duration of stops following the vowels. However, consonants following the vowel /o/ were shorter than other vowel contexts. And the consonant /tt/ was the longest of all the stops in all three vowel contexts.

(3) Effect of aspiration on duration of stop consonants

The distinction between aspirated and unaspirated stop is that aspirated stops are the stops with a breathy murmured release and this release feature is sufficient to make contrast between aspirated and unaspirated stops (Ladefoged and Maddieson 1996, Dixit 1987). Many Indian languages have four-way classification of stops based on voicing and aspiration which is most commonly exhibited by modern Indo-Aryan languages such as Hindi, Marati, and Nepali.

They are Voiced aspirated, voiced unaspirated, unvoiced aspirated, unvoiced unaspirated

According to Ladefoged (1971) and Ladefoged and Maddieson (1996), the breathy release following the voiced aspirated stop differentiates voiced unaspirated stop and voiceless unaspirated stop. They also suggested that only at the release phase of the voiced aspirated stop there was a significant difference in glottal state between voiced unaspirated and aspirated stop. In voiced unaspirated stop there will be a continuous voicing and in voiced aspirated stop, both voicing and aspiration takes place simultaneously at the release phase. Lisker and Abramson (1964), Abramson and Lisker (1967), and Abramson (1977) showed that in many languages including Hindi, voice onset time is the main cue to distinguish between aspirated and unaspirated voiceless stops. They reported that, voiceless unaspirated stops have short-lag VOT and voiceless aspirated stop have long-lag VOT.

The acoustic characteristics of stops and the effect of aspiration have been studied by many in the past. Some of the studies addressed the effect of aspiration on F0 of vowel following the aspirated stops. One of the study by Lai, Huff, Sereno and Jongman (1975) investigated effect of aspiration on F0 of following vowel in Taiwanese language. Ten adult native speakers of Taiwanese participated in the study. They were instructed to read the words presented visually on a laptop computer screen and there utterances were recorded. Results revealed that, F0 of vowel was significantly higher after aspirated stop (187.6 Hz) than after unaspirated stops (184.3 Hz). Zee (1980) compared the effect of aspirated and unaspirated voiceless stops on the F0 of the following

diphthong [ei] in Cantonese. He utilized one minimal pair, /pei/ vs /phei/, and one tone (high level) as stimuli, and tested only three male speakers. He found that diphthong which was followed by aspirated stops have a higher F0 than those with unaspirated stops. He also found that, the intensity of voicing after aspirated stops is lower than after unaspirated stops. He suggested that the intensity difference indicates lower subglottal pressure after aspirated stops. However, the result of F0 onsets of aspirated stops are higher indicates that a higher F0 may be produced even with lower subglottal pressure.

There are very few studies reporting the effect of aspiration on stop consonant duration. Savithri, (1986) studied the effect of aspiration on stop consonant duration in Kannada. Three male and three female Kannada speakers participated in this study. The participants were instructed to read 83 meaningful trisyllabic Kannada words which were visually presented and these were recorded on the screen of the high resolution signal analyzer and the duration of stops were measured. Results revealed that, aspirated stops were 43 ms longer than slightly aspirated stops, their average duration being 169 and 126 ms, respectively.

Torreira (2007) investigated the aspirated stops in Western Andalusian Spanish language. Two (one male and one female) native speakers of Western Andalusian Spanish participated in the study. The speakers were instructed to read a series of target words which consisted of aspirated and unaspirated clusters, embedded in a carrier sentence and these utterances were recorded. Stop closure duration of each word were measured. Results revealed that, the stop closure durations of aspirated cluster were significantly longer than

unaspirated in Western Andalusian Spanish.

(4) Effect of place of articulation on duration of stop consonants

Oral stop consonants are produced by a constriction at different places of articulation for different sounds within the oral cavity. /p/ and /b/ are produced by the constriction by upper and lower lips, /t/ and /d/ produced by the constriction at the dental region with tongue tip, and /k/ and /g/ produced by constriction at the velar region by tongue body. Some of the languages also include retroflex stops which are produced by curling the tongue body towards the alveolar region followed by sudden release. Temporal aspects of the consonants depend upon the place of articulation.

Some of the studies reported the duration measures of the stop consonants in different place of articulation. Kim and Macneilage (1972) analysed the voiceless stop duration of /p/, /t/, /k/ in VCV utterances using digitized oscillographic displays. Eight subjects produced each consonant 10 times in each of the four contexts i-i, i-a, a-i, and a-a. Closure durations for stop consonants were, in decreasing order of /p/ > /t/ >/k/, and burst durations showed the opposite order, results thus tending towards equal total stop consonant durations.

Zue (1976) investigated the closure duration of initial stop consonant which were prestressed English plosives in nonsense CVC utterances embedded in a carrier sentence. These acoustic data were recorded using Presto model 800 tape recorder in a sound proof room. Data was analysed using Digital computers and digital signal processing techniques. He found [p] was produced with longer

duration than [t] and [k].

Repp (1984) investigated the closure duration of /p/, /t/, /k/ in words splat, stlat and sclat uttered by a male speaker of American English reported that, closure duration of labial stop consonant was longer which was followed by velar and then alveolar stop consonant.

Luce and Luce (1985) investigated the closure duration of word final stop consonant in CVC combination in English meaningful words. Results reveal Closure durations for bilabial stop were longer than those for velars which are again longer than those for alveolar stop consonants. They also found that closure durations were longer for the voiceless stops than voiced stop consonants.

Savithri, (1986) studied effect of place of articulation on the duration of stop consonants in Kannada. Three male and three female Kannada speakers in the age range of 22-40 years were participated in the study. The word list consisted of 83 meaningful trisyllabic Kannada words with medial target stop consonants was the test material used in this study. The participants were instructed to read these words and recording was done. Duration of the consonants was measured. Effect of place of articulation seemed to influence the duration of consonants in that the average duration of retroflex was 156.3 ms which was the shortest and that of the palatals was 179 ms, which was longest.

Crystal and House (1988) reported that the duration of closure in alveolar stops are consistently shorter than that of bilabials and velars, while bilabials and

velars are very similar in closure durations.

Crystal and House (1988) analyzed the total duration of stop consonants in English speakers by recordings produced by six talkers reading two scripts of approximately 300 words each. These findings indicate that the total duration of alveolar and labial were similar and were longer for velars.

Byrd (1993) reported the pattern of average closure durations, which were decreased from bilabial to velar to alveolar and average burst durations were increased from bilabial to alveolar to velar in both voiced and voiceless stops in American English according to TIMIT database.

Beruh (2004) investigated the closure duration of stop consonants (/b, d, g/ vs. /p, t, k/) in both word initial and final position of CVC sequence in French language reported that, mean of /p, t, k/ closure durations were significantly longer than mean of /b, d, g/ closure durations for both word initial and word final stops.

Yao (2007) investigated the closure duration and burst duration of English voiceless stops in word-initial position. Nineteen native English speakers participated in this study. It was found that, closure duration was significantly greater for production of a [p] sound than in [t] and [k], consistently across speakers and burst duration was shortest for /p/ than /k/ and /t/. But, there was no significant difference for burst duration across the sounds.

Dommelen1 & Ringen (2007) investigated effect of place of articulation on the duration of pre-aspiration of fortis stops. Eleven native Norwegian speakers

who's dialect background from the Trøndelag region. The speech material consisted of 19 disyllabic words. These words contained intervocalic fortis and lenis stops which were analysed in this study. It was found that, duration of pre-aspiration significantly varied with place of articulation. Longest durations were observed for alveolar stops (45 ms) followed by velars (42 ms) followed bilabials (32 ms).

(5) Effect of gender on duration of stop consonants

In terms of gender, sociolinguists reported that women generally try to produce more standard forms compared to men, in order to avoid the criticism that their position in society subjects them to (Deuchar, 1989; Cheshire, 2002). Trudgill (1986) noted in his study that female speakers tend to produce more strongly released word-final stops than men, as that is considered a more standard and prestigious pronunciation. Similar results are found by Whiteside (1995; 1996), where women were seen to articulate consonant clusters more fully, and also at a slower rate. In the same studies, she also found that men had a higher tendency to delete and lenite sounds. Men were also found to have higher rates of consonant reduction in Byrd's (1994) study of American English speech.

Other studies have also drawn clear relations to gender and production of stops in different languages. Horvath's (1985) earlier study on Sydney English found that females produced more heavily aspirated /t/ and affricated variant then males. Docherty, Hay and Walker's (2006) research on phrase-final /t/ in New Zealand English looked first at whether the stop was released in male and female spontaneous speech. They found that females showed a higher number of released forms than males. This is again showing that women tend to produce

more standard forms of consonant than males.

In terms of studies on stop consonant duration, earlier study by Zue and Laferriere (1979) investigated the acoustic characteristics of medial /t/, /d/ in American English as a function of phonetic environments. Six subjects, three males and three females were participated. The data consisted of a list of 250 words contain medial /t,d/ in six phonetic environments such as prestressed, nasal released, flapped, unstressed, post-nasal and post-lateral environments. Participants were asked to read the words on the list by embedding each word in a carrier phase. All these utterances were recorded using tape recorder. Quantitative-results were obtained on the acoustic characteristics of each stop for all phonetic environments. The results revealed gender based variation in the duration of stops in various phonetic contexts where females duration were significantly longer than males in 14 of 22 relevant durational contexts.. This indicates that, female speakers produce longer segments than men and also tend to articulate the full form with its totality of distinctive features.

Savithri, (1986) studied duration of stop consonants in Kannada as an effect of gender. Three male and three female Kannada speakers in the age range of 22-40 years were participated in the study. Readings of the word list consisted of 83 meaningful trisyllabic Kannada words with medial target stop consonants of all the participants were recorded and duration of the consonants was measured. Results showed that females exhibited longer consonant duration than males.

Botinis, Christofi, Themistocleous & Kyprianou, (2004*)* studied the effect of gender on duration of stop consonants. Five female and five male Cypriot Greek

students participated in this study. Twelve words embedded in the carrier sentence which contains voiced and unvoiced stop consonants were considered as a test material. Participants were instructed to produce these words in ten repetitions. Closure duration, burst duration and total duration were measured. Results revealed that, females produced significantly longer closure duration and total stop duration than males but there was no significant gender effect on burst duration.

Dommelenl & Ringen (2007) investigated gender difference in duration of preaspiration in fortis stops. Eleven subjects aged between 21 and 37 years were participated in this study. Five of them were males, six of them were females. All subjects had their dialect background from the Trøndelag region. The speech material consisted of 19 disyllabic words. These words contained intervocalic fortis and lenis stops which are analysed in this present study. It was found that, preaspiration was the main feature in the production of fortis stops and the average duration of preaspiration was 41 ms. They reported that, female speakers produced longer duration of preaspiration then male which was 46 ms and 35 ms respectively.

Limanni (2009) investigated the gender difference in the production of intervocalic voiced stop consonants in Mexican Spanish. Six native speakers (three males and three females) of a similar variety of Mexican Spanish were participated in this study. Task of the participants includes: (i) a picture identification task where this picture serve to introduce questions meant to elicit the target word embedded in a longer stretch of speech, rather than a single word production, (ii) a story-telling task where speakers were given three sets of

sequential pictures and asked to relate the events in each set and describe the events. These tasks were designed to elicit a casual, conversational speech style. The participants were recorded using CD recorder. The duration and speed of consonant release of intravocalic /b, d, g/ were analysed using Praat software. Results indicated that, female speakers exhibited a longer duration of stops for all the place of articulation. But difference was not statistically significant. The results for speed of consonant release revealed that males had a lower speed of consonant release across all places of articulation. The female speakers averaging a speed of consonant release of 13.4 dB/s compared to 8.1 dB/s for the male speakers. However, as above, this observed difference does not reach statistical significance. This study also reported significant influence on lenition (softening or weakening of sound) which shows that, females' lenite less then the males. This reflects the tendency for females to prefer formal and/or prestige speech variants of stable linguistic variables.

The review reveals effect of (a) voicing, (b) preceding vowel, (c) aspiration, (d) place of articulation, and (e) gender on duration of stop consonants. Voiced stops are shorter than the unvoiced; longer preceding vowels are found before voiced stops; aspirated stops are longer than unaspirated; velars and bilabials are longer than stops in any other place of articulation, and females tend to have longer phonemes than males. However, there are differences between languages depending on the place, voicing, aspiration of stop consonants. In this context the present study investigated the influence of several phonetic factors, and gender on the duration of stop consonants. Specifically, the effect of phonetic factors – voicing, preceding vowel, aspiration and place of articulation – on duration of stop consonants in 18-30 year old

Telugu speakers from Telangana dialect was investigated. Furthermore, the effect of gender on the duration of stop consonants was investigated.

CHAPTER III

METHOD

Participants: Thirty speakers - 15 Male and 15 Female Telugu speakers within the age range of 18 to 30 years - participated in this study. An informed written consent was obtained from the participants. The following were the inclusion criteria.

- Healthy normal individuals with no history of speech and neurological problems at recording time as indicated by the history,
- Age appropriate language abilities as assessed informally by the investigator,
- Hearing sensitivities within normal limits as assessed by ten test, and
- Native speakers of Andhra Pradesh – Telengana Telugu dialect.

Test Material: The stimuli included a list of Telugu meaningful C1V1C2V2 words, where C2 represented one of the following target stop consonants: p, b, ṭ, ḍ, t, d, k, g, p^h, b^h , $ṭ^h$, $ḍ^h$, t^h, d^h, k^h, g^h; V1 was any vowel and V2 was vowel /a/ which was kept constant. Table 1 shows the stop consonants of Telugu and table 2 shows material of the study.

	U		V	
Place of articulation	UA	A	U	M
Velar	k	k^h	g	g^h
Retroflex	ṭ	$ṭ^h$	ḍ	$ḍ^h$
Dental	t	t^h	d	d^h
Bilabial	p	p^h	b	b^h

U = Unvoiced V = Voiced UA = Unaspirated A= Aspirated M = Murmured

Table 1: Stop consonants in Telugu.

Phoneme	Words									
K	ta:ka	le:ka	pe:ka	ra:ka	do:ka	du:ka	pi:ka	ko:ka	po:ka	nu:ka
K	re:ka	ke:ka	to:ka	me:ka	ti:ka	pa:ka				
k^h	ʃa:k^ha									
G	ti:ga	ḍe:ga	ra:ga	ba:ga	d^3a:ga	mu:ga				
g^h	me:g^ha									
ṭ	pa:ṭa	tu:ṭa	bi:ṭa	ta:ṭa	ve:ṭa	ri:ṭa	ko:ṭa	pi:ṭa	tu:ṭa	va:ṭa
ṭ	mu:ṭa	to:ṭa	ba:ṭa	pu:ṭa	tʃa:ṭa	pe:ṭa	lo:ṭa	ma:ṭa	te:ta	ma:ta
ḍ	ma:ḍa	go:ḍa	pi:ḍa	va:ḍa	pe:ḍa	na:da	Vo:da	te:da	ku:da	ka:da
ḍ	dza:da	me:da	so:da	ni:da	tʃi:da					
T	gi:ta	si:ta	me:ta	ta:ta	k^ha:ta	pi:ta	du:ta	mu:ta	tʃe:ta	ro:ta
T	da:ta	pa:ta	ma:ta	pu:ta	ja:ta	ko:ta	ku:ta	le:ta	va:ta	ne:ta
	ra:ta									
D	pe:da	sa:da	so:da	ga:da	mi:da	ge:da	se:da	bi:da		
d^h	ra:d^ha									
P	pa:pa	tʃa:pa	tʃe:pa	di:pa	du:pa	ru:pa	me:pa	ve:pa		
B	ba:ba	ʃo:ba	gu:ba							

Table 2: Material used in the study.

Procedure: Participants were individually tested. Each word was written on a 3" × 3" flash cards. Participants were instructed to read the visually presented words five times. All the readings were audio recorded at 44 kHz sampling frequency using a digital recorder. These five recording of all participants were audio-presented to two native Telugu speakers to decide on the correctness of stop consonants uttered by the

participants. Three best and correctly articulated of five recording were used for further analyses.

Analyses: The words were displayed as waveforms using PRAAT software (Boersma & Weenink, 2013). Total duration, closure duration and Burst duration for the word-medial stop consonant was measured. ***Closure duration*** is the time interval between the offset of V1 (sharp fall in the waveform amplitude) to the consonantal release. ***Burst duration*** is the time duration between the onset and offset of the transient burst. ***Total duration*** is the time duration between the offset of V1 to onset of V2. Figure 1 illustrates the measurement of closure duration and burst duration.

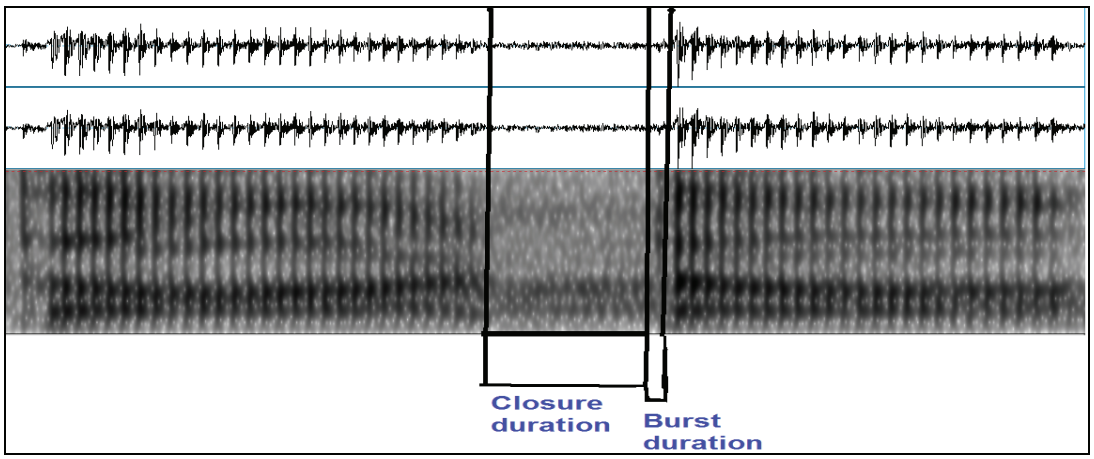

Figure 1: Illustration of measurement of closure duration and burst duration.

Statistical Analyses: A commercially available SPSS was used for statistical analyses. Mixed ANOVA was performed to obtain within subject factors such as effect of voicing, aspiration, preceding vowel duration and place of articulation on stop duration and gender as a between subject factor. When there was a gender effect, further analysis was done by MANOVA within each condition (voiced and unvoiced; aspirated and unaspirated). One way repeated measure ANOVA was done to compare effect of place of articulation in males and females separately.

CHAPTER IV

RESULTS

The results of the study will be discussed under the following headings:

(1) Closure, burst and total duration of stop consonants

(2) Effect of voicing and gender on duration of stop consonants

(3) Effect of preceding vowel and gender on total duration of stop consonants

(4) Effect of aspiration and gender on total duration of stop consonants

(5) Effect of place of articulation and gender on total duration of stop consonants

(1) Closure, burst and total duration of stop consonants

Closure duration of bilabial stops was the longest followed by velar, dental and retroflex. Further aspirated stops were longer than unaspirated stops. Velars had the longest burst duration followed by dental, retroflex, and bilabial places of articulation. Total duration of bilabial stops was the longest followed by velar, dental and retroflex. Table 3, 4, and 5 show the closure duration, burst duration, and total duration of stops in various places of articulation.

	U		V		
Place of Articulation	**UA**	**A**	**UA**	**A**	**Average**
Velar	96	112	79	90	94.25
Retroflex	65	-	48	-	56.50
Dental	87	-	56	72	71.67
Bilabial	130	-	99	-	114.5

U = Unvoiced V = Voiced UA = Unaspirated A= Aspirated M = Murmured

Table 3: Closure duration (ms) of stop consonants in various places of articulation.

Place of Articulation	U		V		Average
	UA	A	UA	A	
Velar	13	16	9	15	13
Retroflex	12	-	8	-	10
Dental	15	-	10	0	12.5
Bilabial	11	-	7	-	9
Average	12	4	8.5	4	10

U = Unvoiced V = Voiced UA = Unaspirated A= Aspirated M = Murmured

Table 4: Burst duration (ms) of stop consonants in various places of articulation.

Place of articulation	U		V		Average
	UA	A	UA	A	
Velar	102	113	71	82	92.0
Retroflex	89	-	56	-	72.5
Dental	96	-	68	77	80.3
Bilabial	128	-	88	-	108.0

U = Unvoiced V = Voiced UA = Unaspirated A= Aspirated M = Murmured

Table 5: Total duration (ms) of stop consonants in various places of articulation.

(2) Effect of voicing and gender on duration of stop consonants

Results of mixed ANOVA showed main effect of voicing [F (1, 28) = 181.674 at $p < 0.001$] and gender [F (1, 28) = 7.603 at $p<0.05$], and no significant interaction between voicing * gender [F (1, 28) = 2.927, $p < 0.05$]. The mean closure duration of unvoiced plosives was significantly longer than that of voiced plosives. Results of MANOVA revealed significant gender difference for unvoiced plosives [F (1, 28) = 9.112, $p \leq 0.05$]. The mean closure duration of unvoiced plosives was longer in females than males. Table 6 shows the mean and standard deviation of closure duration in voiced and unvoiced plosives.

	Unvoiced	Voiced
Male	78.88 (14.26)	52.06 (11.21)
Female	93.15 (11.48)	59.07 (10.92)
Average	86.015	55.565

Table 6: Mean (ms) and SD (in parenthesis) of Closure duration of voiced and Unvoiced stop consonants in both genders.

Effect of voicing and gender on burst duration of the stop consonants

Results of mixed ANOVA showed main effect of voicing [F (1, 28) = 38.808, p < 0.001] and no significant main effect of gender [F (1, 28) = 0.068, p< 0.05]. No significant interaction between voicing* gender [F (1, 28) = 38.808, p < 0.05] was observed. The mean burst duration of unvoiced stop consonants was significantly longer than that of voiced plosives. Table 7 shows the mean and SD of burst duration in voiced and unvoiced plosives.

	Unvoiced	Voiced
Male	14.77 (2.89)	8.55 (5.9)
Female	14.98 (2.13)	8.92 (4.31)
Average	14.875	8.735

Table 7: Mean (ms) and SD (in parenthesis) of burst duration of voiced and Unvoiced stop consonants in both genders.

Effect of voicing and gender on total duration of the stop consonants

Results of mixed ANOVA showed main effect of voicing [F (1, 28) = 351.971, p< 0.001], gender [F (1, 28) = 5.223, p<0.05] and no significant interaction between voicing * gender [F (1, 28) = 1.945, p < 0.05]. The mean total duration of unvoiced plosives was significantly longer than that of voiced plosives. Results of MANOVA indicated gender effect only for unvoiced stop consonants

[F (1, 28) = 6.253, p< 0.05]. The mean total duration of unvoiced plosives was longer in females than males. Table 8 shows the mean and standard deviation of total duration in voiced and unvoiced plosives.

	Unvoiced	Voiced
Male	99.35 (15.55)	57.69 (13.58)
Female	112.74 (13.72)	64. (11.73)
Average	106.045	60.845

Table 8: Mean (ms) and SD (in parenthesis) of total duration of voiced and Unvoiced stop consonants in both genders.

(3) Effect of preceding vowel and gender on total duration of stop consonants

The result of mixed ANOVA showed main effect of preceding vowel [F (4,112) = 10.895, p<0.001] main effect of gender [F (1, 28) = 25.947, p<0.001] and no significant interaction between preceding vowel * gender [F (4, 112) = 7.326, p < 0.001]. The mean stop duration was longest when followed by vowel /u:/ and shortest when followed by vowel /e:/. Females exhibited significantly longer mean durations than males in all the vowel contexts (P<0.05). Further, results showed significant difference between total duration of stop consonants when preceded by /a:/ vs. /e:/, /i:/ vs. /e:/, /u:/ vs. /e:/ /o:/, /e:/ vs. /a:/ /i:/ /u:/ and /o:/vs. /u:/ at P<0.05. Table 9 shows the mean duration and standard deviation of stop consonant duration preceded by different vowels.

	Males	Females	Average
/a:/	80.4 (6.266)	92.12 (6.137)	86.26
/i:/	80.87 (11.3)	93.73 (7.478)	87.30
/u:/	85.13 (10.295)	91.27 (4.832)	88.20
/e:/	74.00 (11.464)	89.20 (5.213)	81.60
/o:/	73.67(8.942)	92.40 (5.654)	83.03
Average	**78.814**	**91.744**	**85.28**

Table 9: Mean (ms) and SD (in parenthesis) of stop consonant duration preceded by different vowels in both genders.

(4) Effect of aspiration and gender on total duration of stop consonants

Results of mixed ANOVA showed main effect of aspiration [F (1, 28) = 7.154, $p < 0.05$], no significant gender effect [F (1, 28) = 2.599, $p<0.05$] and no significant interaction between aspiration * gender [F (1, 28) = 0.030, $p < 0.05$]. The mean total duration of aspirated stop consonants was significantly longer than that of unaspirated stop consonants. Table 10 shows the mean total duration and standard deviation of aspirated and unaspirated stop consonants.

	Aspirated	Unaspirated
Male	79.27 (15.97)	72.61 (12.90)
Female	86.89 (16.23)	79.32 (10.93)
Average	83.08	75.968

Table 10: Mean (ms) and SD (in parenthesis) of total duration of aspirated and unaspirated stop consonants in both genders.

(5) Effect of place of articulation and gender on total duration of stop consonants

Results of mixed ANOVA revealed a main effect of places of articulation [F (3, 84) = 16.515, $p< 0.001$] and gender [F (1, 28) = 4.6955, $p<0.05$], with bilabials

being longest and retroflex stops being shortest consonants. No significant interaction between place of articulation * gender [F (3, 84) = 0.361, p < 0.05] was observed. Results of One way repeated measure ANOVA showed a significant gender difference for velar stop consonants [F (1, 28) = 5. 313, p< 0.05]. The mean total duration of velar stop consonants was significantly longer in females than males. The mean duration and SD values of velar, retroflex, dental and bilabial stop consonants for males and females were shown in Table 11.

	Males	**Females**	**Average**
Velar	80.30 (14.34)	91.77 (12.87)	86.03
Retroflex	63.67 (12.06)	71.03 (11.49)	67.35
Dental	76.14 (16.38)	80.92 (13.55)	78.53
Bilabial	85.03 (13.59)	95.00 (26.451)	90.02
Average	**76.30**	**84.70**	**80.50**

Table 11: Mean duration (ms) and SD (in parenthesis) of stop consonants in various places of articulation in males and females.

To summarize, the results indicated main effect of voicing, aspiration, preceding vowel and place of articulation. Main effect of gender was not consistent. Unvoiced stops (closure, burst and total duration) were significantly longer than voiced stops; aspirated stops were significantly longer than aspirated stops; stops were significantly longer when preceded by vowel /u:/ and shorter when preceded by significantly vowel /e:/; stops in bilabial place of articulation were significantly longer and stops in retroflex place were significantly shorter than those in other places of articulation.

CHAPTER V

DISCUSSION

The results of the study indicated several points of interest. ***First of all, the mean closure duration of unvoiced stop consonants was significantly longer than that of voiced stop consonants.*** These results are in agreement with the earlier studies conducted by Lisker (1957) ; Scharf (1962) where they suggested that mean closure duration of unvoiced stop consonants were longer that voiced stop consonants. **Burst duration of unvoiced stops was significantly longer than voiced stop consonants.** These findings support the Byrd's (1993) report on American English stops in TIMIT database. ***The average total duration of unvoiced stops was significantly longer than the voiced stops.*** Similar findings were reported by Klatt (1976), Sthathopoulous & Weismer (1979), and Savithri (1986) in Kannada. Physiological effect of voicing on closure duration, burst duration and total duration of stop consonants can be explained as following: The articulatory resistance is high in unvoiced stop consonants compared to voiced stop consonants to maintain a constant vocal tract resistance. In the production of unvoiced stops vocal folds are open resulting in zero glottal resistance to the flow of air. In voiced stop consonants, vocal folds are vibrating resulting in some glottal resistance to the flow of air. Hence, articulatory resistance should be higher in unvoiced stops so as to maintain a constant total resistance. As the articulatory resistance is higher in unvoiced stops more volume of air is required to be build up in the oral tract behind the closed articulator which results in longer closure duration and hence longer total duration. Further, in voiced stops a part of the energy is utilized for vocal fold vibration which is not the case in unvoiced stop. This results

in higher amplitude of burst and longer burst duration in unvoiced stops than voiced stops.

Second, the results indicated significantly longer total duration of unvoiced stop consonants in females than males. Similar findings were found in Kannada speech sounds by Savithri (1986); Botinis, Christofi, Themistocleous & Kyprianou. (2004*)* in Cypriot Greek. These may be because females tend to articulate with more precision and its totality of distinctive features which can lead to longer duration of speech sound. Whereas, males tend to produce shorter speech segments and may not reach the exact distinctive features. These gender effects are particularly observed for the voiceless stop consonants but not for voiced stops. These can be because females tend to have longer voice onset time for unvoiced stop consonants than voiced stops compared to males as reported by Robb, Gilbert & Lerman. (2005); Koenig. (2000). As there is a longer lag VOT , these lead to longer total duration of unvoiced stop consonants in females.

Third, the mean total duration of stop was significantly longer when the preceding vowel was /u:/ and shorter when preceding vowel was /e:/. This may be because, speakers tend to maintain the temporal characteristics of syllable by increasing or decreasing the duration of consonant according to the preceding vowel duration. For instance, duration of consonants was longer when followed by the vowel /u:/, as the duration of vowel /u:/ is shorter then /a/ as reported by Sharf's (1962). And also, Female exhibited longer mean durations than males in all the vowel contexts. These may be because, females tend to articulate with more precision and its totality of distinctive features which can lead to slower articulatory gestures.

Fourth, aspirated stops were significantly longer than unaspirated stops. Similar finding were reported by Savithri (1986) in Kannada language. At the release of an aspirated stop, a puff of air runs through the glottis. Because of this air release during the production of stops, there will be a longer consonantal duration which was also observed in this study.

Fifth, total duration of bilabial stops was longest and retroflex was shortest. The main trend was bilabilals > velars> dentals> retroflex. This is in consonance with the results of the study done by Repp (1984) where the order of decrease in the duration was bilabial> velar> alveolar stop consonants in American English. These findings are in agreement with the results of the study by Savithri (1986) which reported that, retroflex stops were shorter in Kannada and in Sanskrit (Savithri, 1983). One of the explanations for the longer duration of bilabial stop consonants is that, when the place of articulation is in the front part of the vocal tract, more volume/ space is available for accumulation of air resulting in longer durations. Another explanation is offered by Lofqvist (1996). He reported that lips exhibit greater velocities at the instants of oral closure. As a consequence, the lower lip continues its upward movement after the closure had occurred and the contact pressure between the lips reaches its maximum when the lower lip reached its highest position. In addition, the stiffness of the lower lip has been reported to be higher at the time of oral contact. So, because of this greater contact pressure between the lips and higher stiffness of lower lip, it requires greater effort and longer time for the lips to release from closure which leads to longer closure duration and longer total duration of bilabial stop consonants. Retroflex stops were shortest than other place of articulation is because, it is probably difficult to curl back the tongue and keep it in palatal position for a longer time. Hence, one may

expect a quick articulatory release resulting in the shorter duration of the retroflex consonants. It was also found that, there was significant gender effect for velar stop consonants revealed the mean duration of velar stop consonants was longer for females than males.

The results of the study have contributed to the literature on duration of stops in Telugu. This study is restricted to investigate the effect of phonetic context such as voicing, aspiration, proceeding vowel and place of articulation and extra linguistic factors on the duration of stop consonants. Future studies on the influence of germination on consonant duration, extralinguistic factors such as speakers' mood, their physical Condition, age and speaking rate, discourse level factors including the difference in duration between the final sentence and the non-final sentence in reading, semantic factors include emphasis and semantic novelty are warranted. Further, this study investigated the duration of stop consonants in word-medial position. Future studies to investigate duration of stop consonants in word-initial and word-final position are warranted. Also, comparison can be made to investigate the durational difference between the dialects of Telugu such as Telengana, Rayalaseema and Seema Andhra.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The speech sounds of language include sonorants and obstruents. Sonorants are produced with continuos, non- turbulent airflow in the vocal tract and most often these are voiced which includes vowels, approximants, nasals, trills. On the other hand, obstruents are produced by obstructing the air flow in the vocal tract which includes stops, fricatives, and affricates. Stop consonants are produced by a complete occlusion in the oral cavity, a build up of pressure behind this closure and a release of the closure allowing the air to be rapidly expelled. Acoustic properties of stop consonants include closure duration, burst duration, aspiration, frication, and coarticulation. Stop consonants also vary according to different place of articulation such as bilabials, dentals, alveolars, retroflex, and velars. Further, stops can be voiced or unvoiced.

Duration plays an important role to understand the nature and organization of speech production, speech perception and phonological theory and also to understand speaker's mood and the locations of the emphasized material. The phonetic identity of different types of segment is cued by their duration. The speech sound heard is determined by the duration of gradually changing speech event such as a formant transition. Duration can also effectively disambiguate syntactically ambiguous sentences even in the absence: of cues provided by fundamental frequency and pauses. In addition, durational data may be of use in applied research areas such as automatic generation of speech for a reading machine for the blind and the automatic recognition of speech from the acoustic waveform.

There are six factors affecting the duration of different speech sound such as extralinguistic factors includes speakers' mood, their physical condition, gender, and speaking rate; discourse level factors includes difference between final sentence and the non-final sentence; semantic factors includes emphasis and semantic novelty; syntactic factors includes word final syllable lengthening; phonetic factors includes aspiration, voicing, retroflex and physiological factors includes effort of articulators.

Several studies have documented that, duration depends on voicing and aspiration. Also, many studies reported that, duration depends on several factors within a language, between the languages and within dialects. In this context, the present study investigated the effect of phonetic factors such as voicing, aspiration and preceding vowel duration on the duration of stop consonants in Telugu speakers from Telangana dialect. Further, the effect of gender on the duration of stop consonants was investigated.

Fifteen male and fifteen female Telugu speakers in the age range of 18-30 years with normal speech, hearing and no neurological problems were selected for this study. Hundred Telugu meaningful words with stop consonants: p, b, ṭ, ḍ, t, d, k, g, p^h, b^h, $ṭ^h$, $ḍ^h$, t^h, d^h, k^h, g^h present in the medial position of the word formed the material. Participants were informed about the study and their written consent was obtained. Each word was written on flash cards and visually presented to the participants and they were instructed to read the words one after the other. These were repeated for five times. These reading were audio recorded using digital voice recorder. These five recordings of each participant were audio presented to two native Telugu speakers to decide on the correctness of stops produced by the participants. Based on these perceptual judgements, three out of five recording which are best and correctly

articulated were used for the analyses. These recorded samples were transferred on to computer memory and analysed using Praat software (Boersma & Weenink, 2013).

The present study investigated closure duration, burst duration and total duration for the word-medial stop consonant. Closure duration was extracted as the time interval between the offset of first vowel to the consonantal release on the waveform. Burst duration was measured as the time duration between the onset and offset of the transient burst on the waveform. Total duration was taken as the time duration between the offset of first vowel to onset of second vowel in each word on the waveform.

The results of the study indicated several points of interest. ***First of all, the mean closure duration of unvoiced stop consonants was significantly longer than that of voiced stop consonants.*** These results are in agreement with the earlier studies conducted by Lisker (1957) ; Scharf (1962) where they suggested that mean closure duration of unvoiced stop consonants were longer that voiced stop consonants. **Burst duration of unvoiced stops was significantly longer than voiced stop consonants.** These findings support the Byrd's (1993) report on American English stops in TIMIT database. ***The average total duration of unvoiced stops was significantly longer than the voiced stops.*** Similar findings were reported by Klatt (1976), Sthathopoulous & Weismer (1979), and Savithri (1986) in Kannada. Physiological effect of voicing on closure duration, burst duration and total duration of stop consonants can be explained as following: The articulatory resistance is high in unvoiced stop consonants compared to voiced stop consonants to maintain a constant vocal tract resistance. In the production of unvoiced stops vocal folds are open resulting in zero glottal resistance to the flow of air. In voiced stop consonants, vocal folds are vibrating

resulting in some glottal resistance to the flow of air. Hence, articulatory resistance should be higher in unvoiced stops so as to maintain a constant total resistance. As the articulatory resistance is higher in unvoiced stops more volume of air is required to be build up in the oral tract behind the closed articulator which results in longer closure duration and hence longer total duration. Further, in voiced stops a part of the energy is utilized for vocal fold vibration which is not the case in unvoiced stop. This results in higher amplitude burst and longer burst in unvoiced stops than voiced stops.

Second, the results indicated significantly longer total duration of unvoiced stop consonants in females than males. Similar findings were found in Kannada speech sounds by Savithri (1986); Botinis, Christofi, Themistocleous & Kyprianou. (2004*)* in Cypriot Greek. These may be because females tend to articulate with more precision and its totality of distinctive features which can lead to longer duration of speech sound. Whereas, males tend to produce shorter speech segments and may not reach the exact distinctive features. These gender effects are particularly observed for the voiceless stop consonants but not for voiced stops. These can be because females tend to have longer voice onset time for unvoiced stop consonants than voiced stops compared to males as reported by Robb, Gilbert & Lerman. (2005); Koenig. (2000). As there is a longer lag VOT , these lead to longer total duration of unvoiced stop consonants in females.

Third, the mean total duration of stop was significantly longer when the preceding vowel was /u:/ and shorter when preceding vowel was /e:/. This may be because, speakers tend to maintain the temporal characteristics of syllable by increasing or decreasing the duration of consonant according to the preceding vowel duration. For instance, duration of consonants was longer when followed by the vowel /u:/, as the

duration of vowel /u:/ is shorter then /a/ as reported by Sharf's (1962). And also, Female exhibited longer mean durations than males in all the vowel contexts. These may be because, females tend to articulate with more precision and its totality of distinctive features which can lead to slower articulatory gestures.

Fourth, aspirated stops were significantly longer than unaspirated stops. Similar finding were reported by Savithri (1986) in Kannada language. At the release of an aspirated stop, a puff of air runs through the glottis. Because of this air release during the production of stops, there will be a longer consonantal duration which was also observed in this study.

Fifth, total duration of bilabial stops was longest and retroflex was shortest. The main trend was bilabilals > velars> dentals> retroflex. This is in consonance with the results of the study done by Repp (1984) where the order of decrease in the duration was bilabial> velar> alveolar stop consonants in American English. These findings are in agreement with the results of the study by Savithri (1986) which reported that, retroflex stops were shorter in Kannada and in Sanskrit (Savithri, 1983). One of the explanations for the longer duration of bilabial stop consonants is that, when the place of articulation is in the front part of the vocal tract, more volume/ space is available for accumulation of air resulting in longer durations. Another explanation is offered by Lofqvist (1996). He reported that lips exhibit greater velocities at the instants of oral closure. As a consequence, the lower lip continues its upward movement after the closure had occurred and the contact pressure between the lips reaches its maximum when the lower lip reached its highest position. In addition, the stiffness of the lower lip has been reported to be higher at the time of oral contact. So, because of this greater contact pressure between the lips and higher stiffness of lower lip, it requires

greater effort and longer time for the lips to release from closure which leads to longer closure duration and longer total duration of bilabial stop consonants. Retroflex stops were shortest than other place of articulation is because, it is probably difficult to curl back the tongue and keep it in palatal position for a longer time. Hence, one may expect a quick articulatory release resulting in the shorter duration of the retroflex consonants. It was also found that, there was significant gender effect for velar stop consonants revealed the mean duration of velar stop consonants was longer for females than males.

The results of the study have contributed to the literature on duration of stops in Telugu. This study is restricted to investigate the effect of phonetic context such as voicing, aspiration, proceeding vowel and place of articulation and extra linguistic factors on the duration of stop consonants. Future studies on the influence of germination on consonant duration, extralinguistic factors such as speakers' mood, their physical Condition, age and speaking rate, discourse level factors including the difference in duration between the final sentence and the non-final sentence in reading, semantic factors include emphasis and semantic novelty are warranted. Further, this study investigated the duration of stop consonants in word-medial position. Future studies to investigate duration of stop consonants in word-initial and word-final position are warranted. Also, comparison can be made to investigate the durational difference between the dialects of Telugu such as Telengana, Rayalaseema and Seema Andhra.

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